Oil for the World

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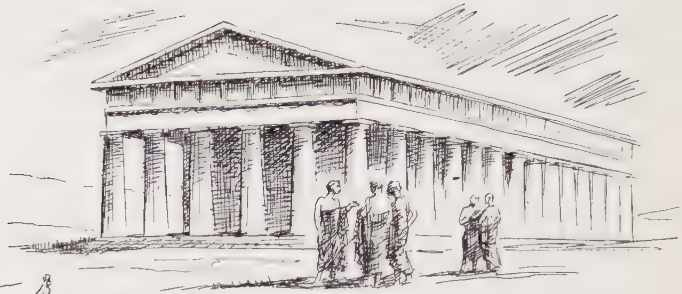
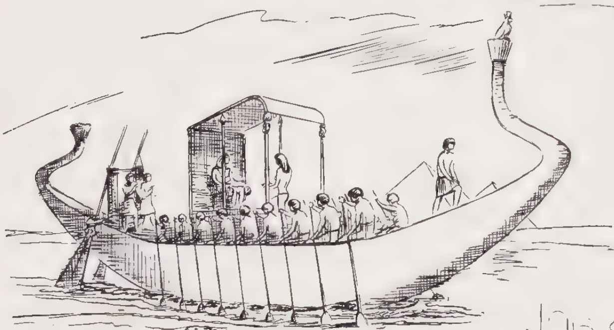




1

At various times in the past there have been periods described as "golden." Learning flourished. Great works of literature and art were produced. Splendid architectural and engineering works were built. And side by side with magnificent accomplishments in these fields, daily life was marked by leisure and graciousness.

The glitter of these "golden" ages sometimes obscures the fact that they had another characteristic which was not so attractive. They were often built on a foundation of slave labor. Education, comfort, and leisure were enjoyed by a relatively small fraction of the people. These societies might be compared to a pyramid of which only the tip was golden and the great bulk was drab clay.

Only within a brief recent period has there been even the possibility of a high standard of living for the great mass of people over any sizable part of the earth. Until recently the basic necessities of life—food, clothes, and shelter—had to be produced by man-power or animal-power. Each individual turned out only a little more than he consumed himself.

When most of the people in any group must give all their energy to producing the basic necessities, only a few can be scholars, scientists, artists, and teachers. But if the necessities can be provided by the work of a few, or by the part-time work of many, the result is leisure, time for cultivation of intellect and spirit, and all the other features of a high civilization.

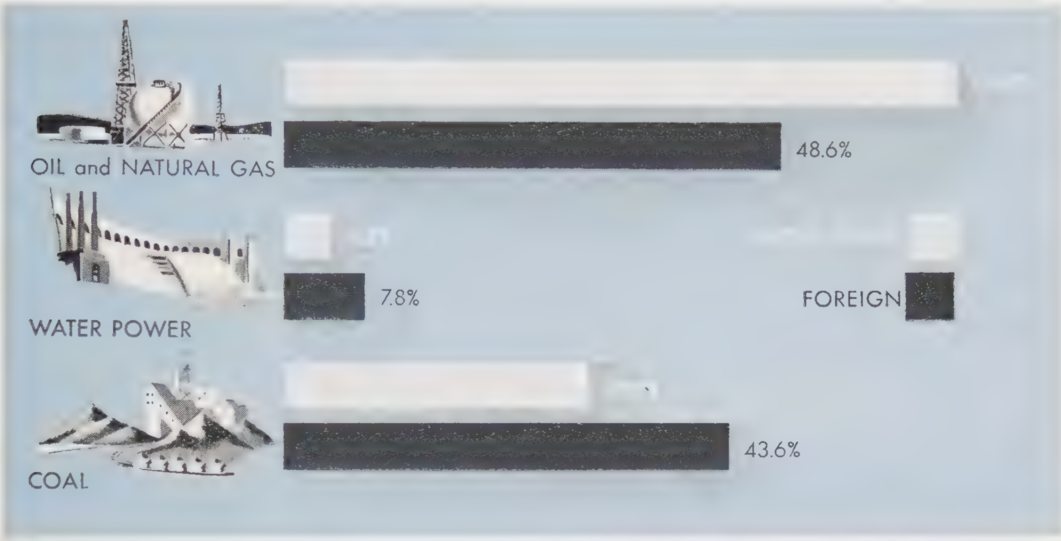
Modern times have seen the development of methods for producing food, clothing, and other necessities with little labor in relation to the abundance of goods turned out.

This condition has been brought about by the use of chemical energy supplied in various forms by nature. The materials in which this chemical energy is locked are generally classed as fuels. By inventing machines to change the chemical energy of fuel into mechanical energy, man has gained power far beyond any he ever had before to perform his work. No longer is his power limited by the strength of his own muscles and the muscles of domesticated animals. Fuels have become the great servants of mankind, relieving people of drudgery and making their efforts many times more productive.

There are wide differences in the amount of fuel energy used by people in different parts of the world, and the productivity and standard of living in different areas vary with the amount of energy employed. For example, the United States, with 7 per cent of the world's population, accounts for 51 per cent of the free world's current fuel consumption. This is more than eight times as much per person as the aver-

age for the rest of the world. As a result, the United States produces two to four times as much goods per labor hour as even the most highly industrialized nations of Europe.

One of the principal sources of fuel energy today is oil, or—as it is called in its crude state as it comes from the ground —*petroleum*. Almost half of the energy used in the world



ESTIMATED SOURCES OF ENERGY IN 1953, UNITED STATES AND ABROAD

today is obtained from petroleum and natural gas, which usually is found with petroleum in the earth. In the United States, 66 per cent of all the energy used comes from those sources. A smaller portion is obtained from coal. The rest is supplied by water-power, with insignificant amounts coming from wood and other fuels. It has been estimated that the energy available from our nation's current output of petroleum is equivalent to the work of about 25 billion able-bodied human workers laboring eight hours a day, five days a week. This fantastically huge labor force would

equal about eleven times as many people as there are in the world.

In the past fifteen years the amount of energy used in the United States has approximately doubled, and almost the whole increase has been provided by additional supplies of oil and gas.

The great importance of oil in the present world economy arises not only from its large contribution to the total energy supply but also from its role as the source of *liquid* energy and from its versatility as a raw material.

Liquid fuels offer many unique advantages. Because they will flow in pipes, they can be easily moved and fed into machines. They present no problem of ash disposal. They contain a very high amount of energy in relation to their weight. For example, a pound of gasoline contains a fourth more potential energy than a pound of coal, and two and one-half times as much as wood. It is these qualities which make liquid fuel from petroleum the best energy source for transportation now available. It would not be feasible, for example, to fly an airplane using coal or electric storage batteries for power—the energy supply would weigh so much that the plane could not lift itself and fly away.

Oil, then, is the great mover. It has made modern transportation possible. The world's automobiles, airplanes, trucks, tractors, and other vehicles are powered by petroleum. Ocean-going ships are almost entirely oil-burning. An oil-driven ship can travel three times as far without refueling as a similar ship using coal. The world's railroads are turning more and more to the use of diesel locomotives, which use oil fuel. Trains pulled by such locomotives can be run at lower cost per mile than trains pulled by steam locomotives. Diesels are smoother in operation, too, and can make far longer runs without refueling.

Man's ability to sustain his life is primarily a matter of ob-

WOOD: 7,500 B.t.u.'s per pound.

CRUDE OIL contains about 19,000 B.t.u.'s of energy per pound.

GRAIN ALCOHOL: 11,760 B.t.u.'s per pound.

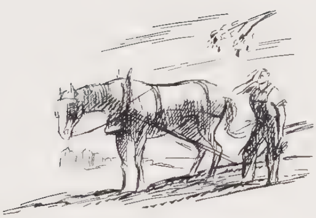
COAL: 15,000 B.t.u.'s per pound (on an average).

ENERGY FROM OIL

Oil contains more B.t.u.'s per pound than wood, grain alcohol, or coal. A B.t.u. (British thermal unit) is the amount of heat required to raise the temperature of one pound of water one Fahrenheit degree. The oil consumed in the United States in 1953, measured as energy, is estimated to have been equivalent to 16,200 trillions of B.t.u.'s; the coal consumed is estimated at 11,500 trillions of B.t.u.'s.

taining food. A development that has multiplied by many times man's ability to grow food is the use of motor-powered farm tools. Today a farmer with power-driven equipment can produce an acre of wheat with one-thirtieth of the man-hours expended by a farmer of a hundred years ago using hand tools. A hundred years ago it took nearly two-thirds of the total labor force to run the nation's farms. Now, less than a seventh of the labor force is required. The use of farm machinery—powered and lubricated by oil—has made the United States a land of abundant food.

Other uses of petroleum in agriculture include the flue-curing or "toasting" of tobacco and the barn-drying of hay by various types of oil burners. The quick-drying of hay by controlled heat is reported to result in a food which is much more nourishing for livestock than sun-cured hay. Petroleum-derived products are also used to spray truck gardens and fruit orchards as protection against bugs and fungus growths. Other oil products are used as weed killers.

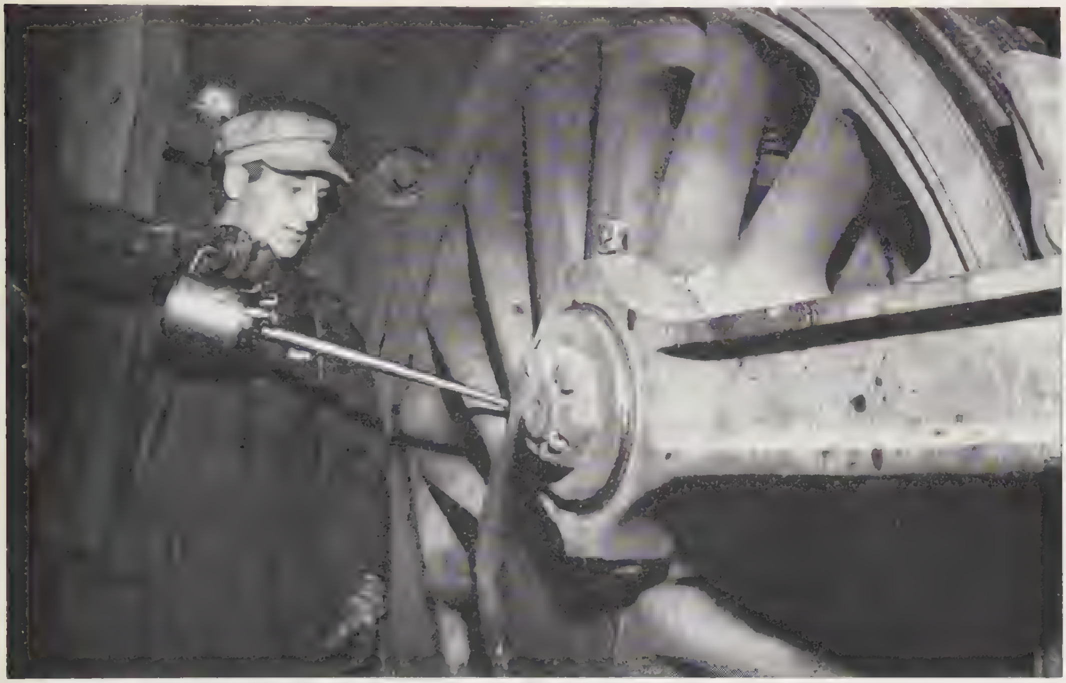


Oil fuels are widely employed in stationary power installations. They provide the energy to run the machines in many factories. Heavy fuel oil, burned under the boilers of central generating stations, produces steam to turn the giant generators. And from the generators flows the electricity that lights our homes and streets, moves trolley cars, and operates our toasters, refrigerators, and radios.

Oil also furnishes heat for houses, apartments, and office buildings. The first domestic oil burner with thermostatic control was put on the market in 1918; in the United States today 6½ million homes are centrally heated by oil. More than 8 million other dwelling places are heated by portable space heaters which burn kerosene.

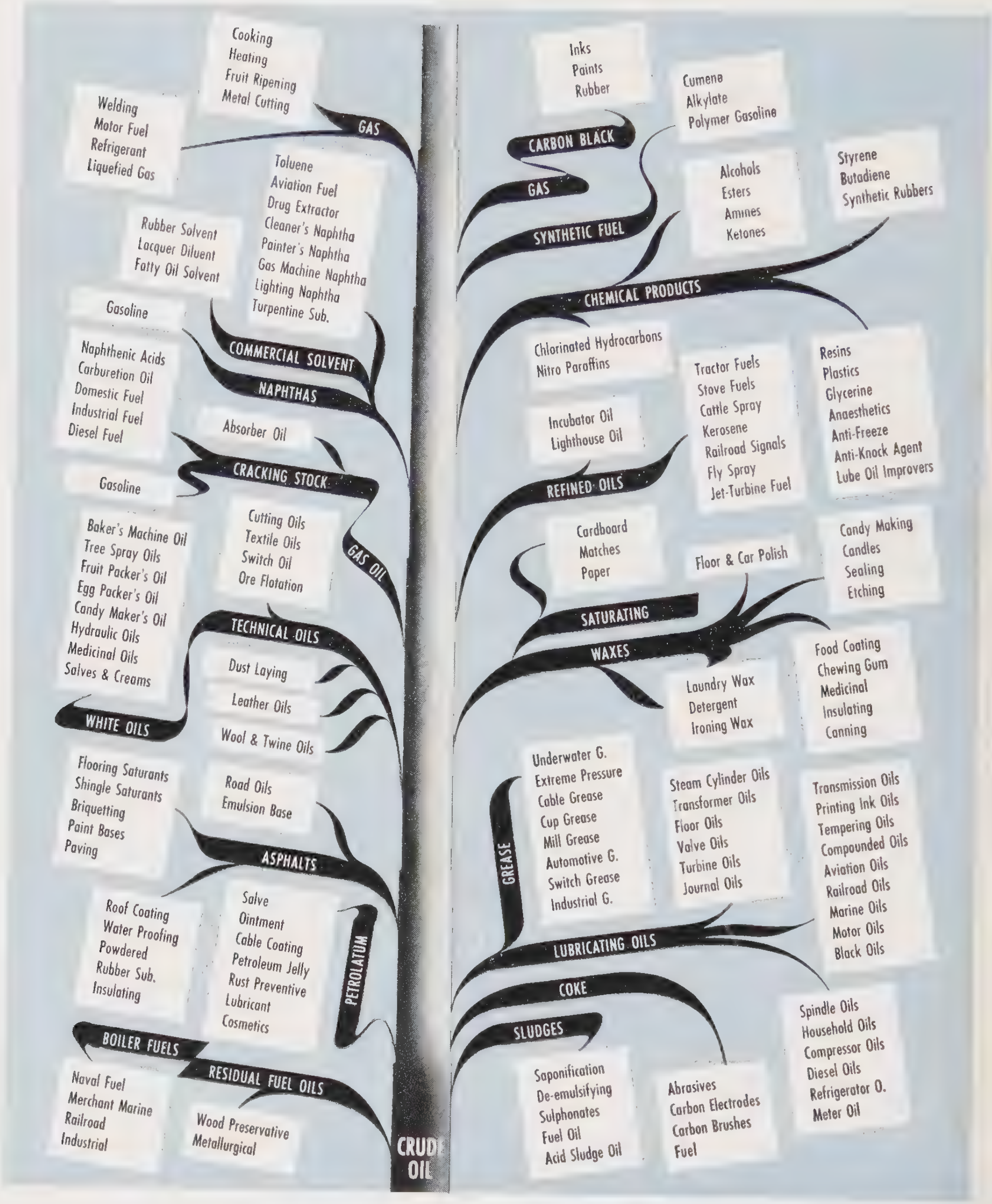
Modern industry, like modern transportation, depends on machines—and wherever there is machinery, there is need for lubricants. "Lubricate" comes from the Latin word

lubricus, meaning "slippery." If gears and pistons are not properly lubricated, that is, if they are not slippery as they rub against other metal parts, the friction created by their motion produces excessive wear and also heat which may cause them to warp and swell so they cannot move. Without oils and greases most of the world's machines would soon be held motionless in the grip of friction.



LUBRICATION

At the beginning of the Machine Age, men had to depend for lubricants on beef or mutton tallow, lard, whale oil, palm oil, or olive oil. There would not be nearly enough of these oils for all of today's factories and vehicles. Besides, most of them are not satisfactory lubricants for modern



PETROLEUM IS USED IN MANY WAYS

machines, which almost without exception are lubricated by petroleum products.

There are hundreds of petroleum lubricants, each of them planned to fit a special need. They may be liquid oils. They may be greases soft as butter or hard as chunks of wood. Some may be dyed to give them an attractive color, or perfumed to make them smell pleasant. Properly applied, they tend to separate parts of machines that would otherwise bear on each other, such as a spinning shaft and its bearing. Lubricants, therefore, reduce the metal-to-metal contact that causes excessive heat and wear.

Petroleum is also used in many other ways. From oil comes asphalt to pave roads, roof houses, and waterproof hundreds of articles. From oil comes wax for candles, waxed paper, and the typist's carbon paper. From oil come artificial rubber and other synthetic plastics with unique and highly useful properties.

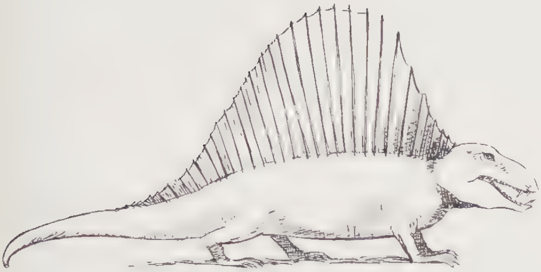
In your family medicine cabinet there are perhaps cold cream, hand lotion, lipstick, perfume, hair tonic, mineral oil, rubbing alcohol, and ointments. All may be made from petroleum or contain petroleum products.

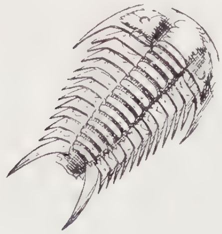
Look at the floor under your feet. Is it covered with carpet? The wool was treated with oil before it was woven. Is the floor varnished? Oil went into the varnish. Is it waxed? The wax probably came from oil.

Look at your feet themselves. Are your shoes made of leather? Oil is used in treating leather goods. Look at your clothing. No oil there? But there is. Oil lubricated the strands of cotton or wool from which it was made. Oil may have helped to dye the cloth. Certainly oil removed the dirt, if you sent the garments to a cleaner.

Look around your house. Oil probably went into the paint on your woodwork and furniture. The inks in your newspapers and magazines contain oil; so do the plastics in

your telephone, your car, and some of your kitchenware; so do the sprays that keep away moths and other insects. Some of the food you eat may have been ripened or preserved by oil. Certainly most of it was grown and carried to you with the aid of oil-driven machines.





2

The youngest crude oil was formed perhaps a little over 10 million years ago. The oldest was formed perhaps some 440 million years ago.

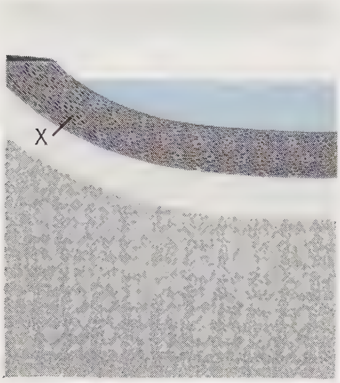
During this vast span of time the earth was gradually changing. There were no animals then of the kind with which we are now familiar. Much of the earth's surface that is now dry land was repeatedly covered by the sea. In those seas, around the margins of the ancient continents, was a teeming life of countless billions of tiny sea creatures. These microorganisms depended for their food upon marine plant life into which the sun continuously poured its energy.

As these minute animals died, their bodies settled down to the sea bottom where they mingled with decaying vegetable matter and the fine silts washed into the seas by the rivers. This was the raw material from which crude petroleum was derived.

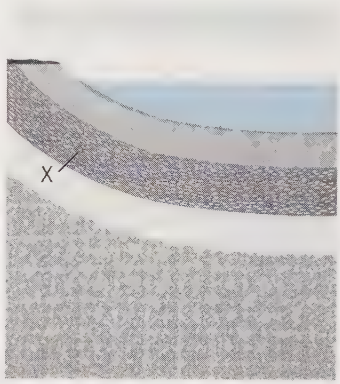
How the entombed organic matter came to be transformed into oil is something about which we are not very certain. Research workers are today studying the question

along the three lines of chemistry, radioactivity, and bacteriology. As so often happens in nature, we shall probably find not one but several modes of origin involved. The old idea that great heat and pressure were necessary has been largely discarded, and instead we have substituted the idea of quick burial and quick transformation into oil, without

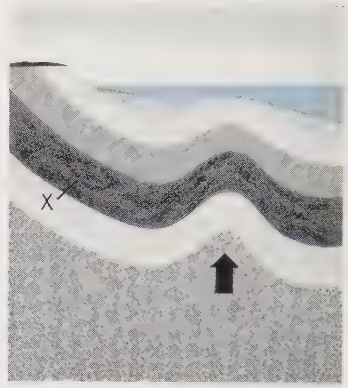
"BURIED SUNLIGHT"



The remains of marine plants and animals settled to the sea bottom (X), mingled with sand and mud.



Rivers emptying into the sea brought more organic remains and silt, covering earlier deposits.



Bacteria or other agents turned the organic matter into oil and gas. Earth forces buckled the strata.

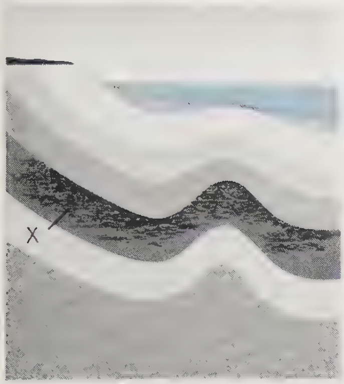
the need for a big weight of overlying rock to assist in the process. It has been said that coal is "fossilized sunlight" that fell on the land areas of the ancient world whereas petroleum is the "fossilized sunlight" that fell on the seas.

The processes that formed oil produced natural gas also, with the result that oil, as it occurs underground, nearly always has gas associated with it.

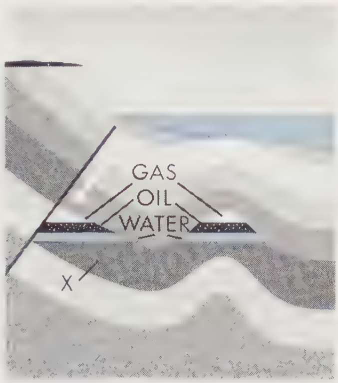
All during the time that the dead organic matter was being transformed into petroleum and gas, fine sediments continued to settle on the sea floor. As their weight increased, the sediments were compressed into rock strata. Droplets of newly formed oil and small bubbles of gas moved out of the muds in which they were generated and into porous

rocks nearby in which they could accumulate. Such porous rocks were generally either sandstones or limestones.

Throughout the millions of years during which this occurred, many structural changes took place on earth. In fact, our planet has behaved almost as a living thing, which "breathes" and thereby stretches and relaxes its skin. As the



The stratum (X), now compressed into porous rock, holds oil and gas. Imprisoned with them is salt water.



Oil and gas migrate until stopped by impervious rock. They form separate layers above the water.

Wells are drilled to seek the buried formation. They may find oil or gas—or only water or a dry area.

earth's crust rose and fell, mountain ranges formed and disappeared; in some places cracks—or *faults*—developed, while in other places, where the land sank, the waters of ancient oceans rushed in to form great seas between the mountains. It was within these long sea troughs or basins that maximum marine sedimentation originally took place, and it is there that our modern oil fields are located.

The face of the earth is still changing, of course, although it may change very little in one person's lifetime. But hills and mountains are still worn down by wind and rain, rivers flood and change their courses, shorelines are built up or eaten away by shifting currents. If a million years of time were compressed into a single day, we would see the earth

in rapid change. Oceans would dry up in a few of those days; new mountain chains would rise while old ones were leveled; continents would appear from under water and sink again beneath the waves. Thus, although oil deposits were originally laid down on sea bottoms, oil is often found hundreds or thousands of miles from today's oceans, sometimes

ORDOVICIAN

430-370 million years ago

PENNSYLVANIAN

265-235 million years ago

CRETACEOUS

135-75 million years ago

even under deserts. Many of these regions appear to have been under water and then above water several times.

Oil occurs in many parts of the world but only where there are marine sediments. Geologists estimate that more than one-third of the land surface of the earth has marine sedimentary rocks under it. But not all of these can be regarded as favorable for oil accumulation. In many, the organic content was too low. In others, the buckling of the earth's crust destroyed the pore spaces so that the oil was lost. Even so, there remains a total of 15 million square miles of the earth's surface which, geologically, offers prospects

for finding oil. About 10 per cent of this area lies in the United States.

In speaking of the amounts of oil to be found underground, we must bear in mind the difference in meaning between two terms used in the oil industry. These two terms are *reserves* and *resources*.

TERTIARY

75-11 million years ago

QUATERNARY

Present day

In different geologic periods, much of what is now North America was under water, making possible formation of oil. Black spots on Quaternary map show present oil areas.

Reserves—or *proved reserves*, as they are sometimes called—refer to oil which is still in the ground but has actually been discovered. This oil is the industry's underground stock or inventory. It does not include oil which undoubtedly exists but either has not yet been precisely located and measured or is not recoverable by present methods.

Resources—also called *ultimate resources*—refer to the total quantity of oil which it is estimated may be found and produced in a particular place. It includes both the oil already discovered and the oil which, on the basis of the most scientific guess possible, may be discovered and produced.

OIL REGIONS OF THE EARTH. Black areas show where oil may be found.

LAKE MARACAIBO

Under Lake Maracaibo, in Venezuela, is one of the world's richest petroleum deposits. The derricks for the underwater wells stand on steel and concrete piles, sometimes in water more than 100 feet deep.

There are a number of areas of the earth where conditions appear to have been particularly favorable for the occurrence of oil.

First, there is the land area bordering the Gulf of Mexico and Caribbean Sea. This region includes the parts of the United States bordering the Gulf of Mexico, eastern Mexico, and Central America, the countries along the north coast of South America, and the islands of the West Indies.

The proved reserves of this Gulf-Caribbean region are generally estimated to be 30 billion barrels. Much of the area—including even that part which lies within the United States, the world's largest producer of oil to date—has not been thoroughly tested. It is certain that there is much more oil yet to be found here.

From this area has come about 40 per cent of the oil which the world has used so far. It is still, measured by present production, the world's chief oil region. But it is not, in regard to future potential, the richest of the world's great oil-bearing areas.

Then there are the west coast and mid-continent area of the United States, both of which play a large part in meeting our nation's oil needs. Also in North America, new oil discoveries in Canada indicate reserves of great possible significance.

Another great petroleum region lies in the Middle East, in the lands bordering the eastern end of the Mediterranean Sea, the Caspian, Red, and Black seas, and the Persian Gulf. It is believed that more oil will eventually be produced in this region than anywhere else in the world. Here are the rich deposits of Iran, Iraq, southwestern Russia, Saudi Arabia, and Kuwait.

Even without thorough exploration, the Middle East has, in the opinion of some authorities, proved reserves of some 80 billion barrels, and these are being added to rapidly.

Estimates of ultimate resources run over 200 billion barrels. Yet it is only within recent years that any attempt has been made to develop, on a large scale, the oil resources of this vast region. It is interesting to think that, although civilization first arose in this part of the earth, its great petroleum wealth lay almost entirely undeveloped and useless until long after the techniques of the oil industry were devised in the New World. For centuries, empires rose and fell in these biblical lands, conquerors marched and countermarched, and nomads tended their flocks, but neither king nor poorest tribesman knew that beneath his feet lay the energy locked in vast amounts of oil.

At the beginning of the twentieth century the growing need for oil and an increasing knowledge of how to find it combined to bring these long-buried energy resources into use. Commercial production from oil deposits began in Iran in 1913, in Iraq during 1934, and in Saudi Arabia in 1938. Within just a few decades, this area has shown itself to be perhaps the earth's greatest storehouse of petroleum. The Eastern Hemisphere, especially Europe, draws most of its oil supplies from the Middle East; the Western Hemisphere requires all its own oil resources to supply its own needs.

Russia is already a large oil producer and has great additional prospects.

There is also a petroleum region lying between Asia and Australia made up of the islands of the East Indies. The chief fields are on Sumatra, Java, Borneo, Tarakan, and Ceram. The proved reserves of this region are over 2 billion barrels, but exploration is far from complete and the ultimate resources are probably considerably larger.

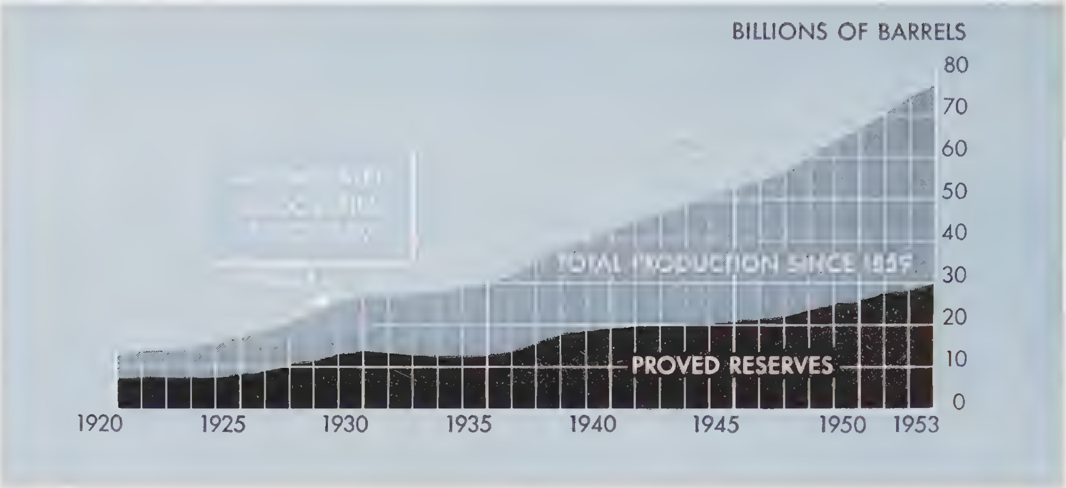
Little is known as yet about the oil possibilities of the land surrounding the Arctic Ocean—the northern edges of Canada, Alaska, Siberia, and Russia. In the distant past the Arctic climate was far warmer than it is now, and geological

conditions there are believed favorable for the occurrence of oil. At some places, such as Point Barrow, Alaska, oil seeps from the ground in such amounts as to lead to a guess that there must be large quantities of it beneath the surface. A small field has been developed in northern Canada near the Arctic Circle, and it is reported that Russian scientists have discovered oil on the Arctic shores of their nation.

Weather conditions in this area would complicate the problem of getting oil out of the ground and to places where it would be useful to mankind. But if this oil is ever needed badly, one can be sure that the people of the oil industry, who have already shown such ingenuity in meeting difficult problems put to them by nature, will find ways to get the Arctic oil to market in spite of storms, ice, and cold.

In addition to the areas mentioned, other oil regions of varying importance are scattered throughout the world. Small fields exist in Austria, Hungary, Germany, the Netherlands, and Poland. Peru, Argentina, and other Latin American countries produce oil on a commercial scale; and there are minor fields in Japan and Sakhalin. At the present time, however, the great bulk of the world's oil comes from the Caribbean area, the United States mid-continent and west coast areas, the Middle East, Russia, and the East Indies.

Withdrawal of oil from producing fields is constantly subtracting from proved reserves. On the other hand, proved reserves are being constantly added to by discoveries of new fields and by finding out that known fields are larger than at first supposed. The situation may be compared with a reservoir holding a city's water supply. The amount in the reservoir at any one time may represent the city's water consumption for only a few weeks. But this does not mean that the city will run out of water in that time, because, as the water is drained out of the reservoir and used, new water comes in.



OIL RESERVES AND WITHDRAWALS IN THE UNITED STATES

Although production of oil has steadily increased, new discoveries have exceeded the amount used.

In the United States, proved reserves of oil in the year 1920 amounted to 7.2 billion barrels. Yet since then, almost six times that quantity of oil has been withdrawn from domestic fields and, despite those withdrawals, proved reserves at the end of 1953 stood at 29 billion barrels. This is the highest figure for proved reserves in the history of the nation.

The world's proved reserves at the end of 1953 totaled over 136 billion barrels.

3

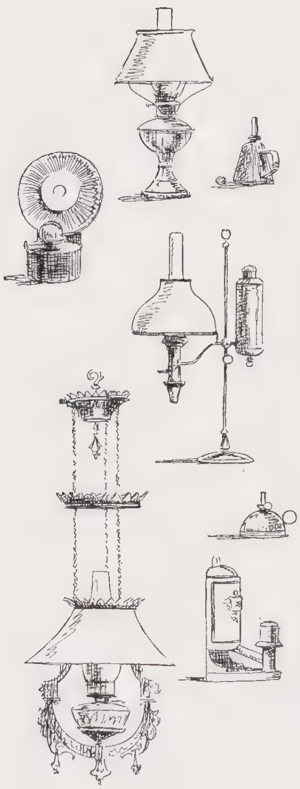
Although mankind has known about oil since the dawn of history, the oil industry is less than one hundred years old. And although men have used oil for thousands of years, it is only in modern times that they have used it as a source of energy to do a large share of the world's work. It is this particular use of oil which is one of the chief characteristics of contemporary civilization.

In widely scattered parts of the globe, oil oozes from the earth in the form of petroleum seepages, or finds its way to the surface of streams. George Washington reported in his will that he had acquired a tract of land in western Pennsylvania because of "a bituminous spring which it contains, of so inflammable a nature as to burn as freely as spirits, and is as nearly difficult to extinguish."

It is likely that in early times men used such oil as an ointment, or for waterproofing, or to make torches by dipping reeds and twigs in it. The cult of fire worship in the Middle East centered around "eternal fires" fueled by gas escaping from the rocks and probably ignited by lightning.

During the ancient civilizations of the Mediterranean world, shallow pits were dug in the ground so that oil from seepages would accumulate in them. Pitch or asphalt taken from these sticky pools was used to coat wooden ships and make them more seaworthy. Pitch was used to bind bricks and stones together for buildings. Rubbed on baskets it made them waterproof—the floating cradle in which Pharaoh's daughter found Moses had been fashioned in this way. Nebuchadnezzar paved roads of Babylon and the terraces of the hanging gardens with crude asphalt. Egyptians, Chinese, and the American Indians drank crude oil as a medicine and used it to cover wounds.

Even in ancient times oil was burned as a fuel. It tipped fiery arrows, which were shot over the walls of besieged cities. In the houses of Egyptians and other people of long ago, oil was burned in lamps. Naturally the fact that oil was so useful, yet so scarce and laborious to collect, made it a very precious commodity which relatively few people could afford.



Because his eyes are not so keen as a cat's, nor his nose so sensitive as a dog's, one of man's greatest enemies always has been darkness, and one of his greatest needs has been some way to see at night. In the middle of the nineteenth century, when today's oil industry was born in America, the principal source of light was tallow candles or lamps fed by whale oil. Whaling, in fact, was a major United States industry. Its products not only were used at home but were exported to provide an important source of personal wealth and government revenues of the young republic. Intensive hunting, however, was beginning to deplete the number of whales in the seas.

At this same time, a small amount of lamp oil was being produced from petroleum. Crude oil skimmed from ponds was processed by primitive methods to make a product

called kerosene. About fifty small refineries in the United States were distilling laboriously collected *rock oil.*

There were similar simple refineries in Rumania and other parts of the world where there was a local surface supply of petroleum. In England, coal was being retorted, or "cooked," to produce artificial gas and, in the process, a liquid known as *coal oil* was also produced and sold to fill lamps. In Scotland, oil shale was being roasted to extract from it a thick oil product.

The growing demand for oil created a strong incentive for devising a way to get more of it, but it was not until the late 1850's that the idea occurred to anyone to drill a well with the deliberate intention of getting oil. Methods for drilling water wells were already established. In addition, wells were drilled in some parts of the United States to tap underground pools of brine for the production of salt. When water wells or brine wells were spoiled by oil flowing into them, it was regarded as a misfortune.

Nobody knows for sure who first had the idea of drilling a well to find oil. Most historians say it was George H. Bissell, a New York lawyer. Bissell became interested in the kerosene business and acquired a tract of land, known for oil seepages, on Oil Creek near Titusville in western Pennsylvania. Bissell was one of the organizers of the Pennsylvania Rock Oil Company, which was later renamed the Seneca Oil Company. It was the Seneca Oil Company that drilled the first oil well.

The man who planned and supervised the actual drilling was Edwin L. Drake, a 40-year-old resident of New Haven, Connecticut, who had retired from his job as a railroad conductor because of illness, and so was out of work at the time. The oil company hired Drake and sent him to Titusville to inspect the property, select a site, and drill a well. While he was on this trip, his employers sent him letters addressed to

"Colonel" Drake—to impress the inhabitants of Titusville—and the title stuck.

Before digging the well, Drake erected a wooden tower with a pulley fixed inside its peak and strung a rope over the pulley. This tower, or *derrick*, was used to lower and raise drilling tools in and out of the well. The actual drilling was done with a kind of heavy battering ram which was raised and dropped by an arrangement called a *walking beam*. The walking beam, a long wooden pole, was pivoted at one end. The other end was moved up and down by a steam engine, and the battering ram was suspended in the middle.

Although this operation was familiar to people of the neighborhood as the standard means for digging water wells, the idea of digging a well for oil seemed so strange that the project and its equipment were dubbed "Drake's Folly."

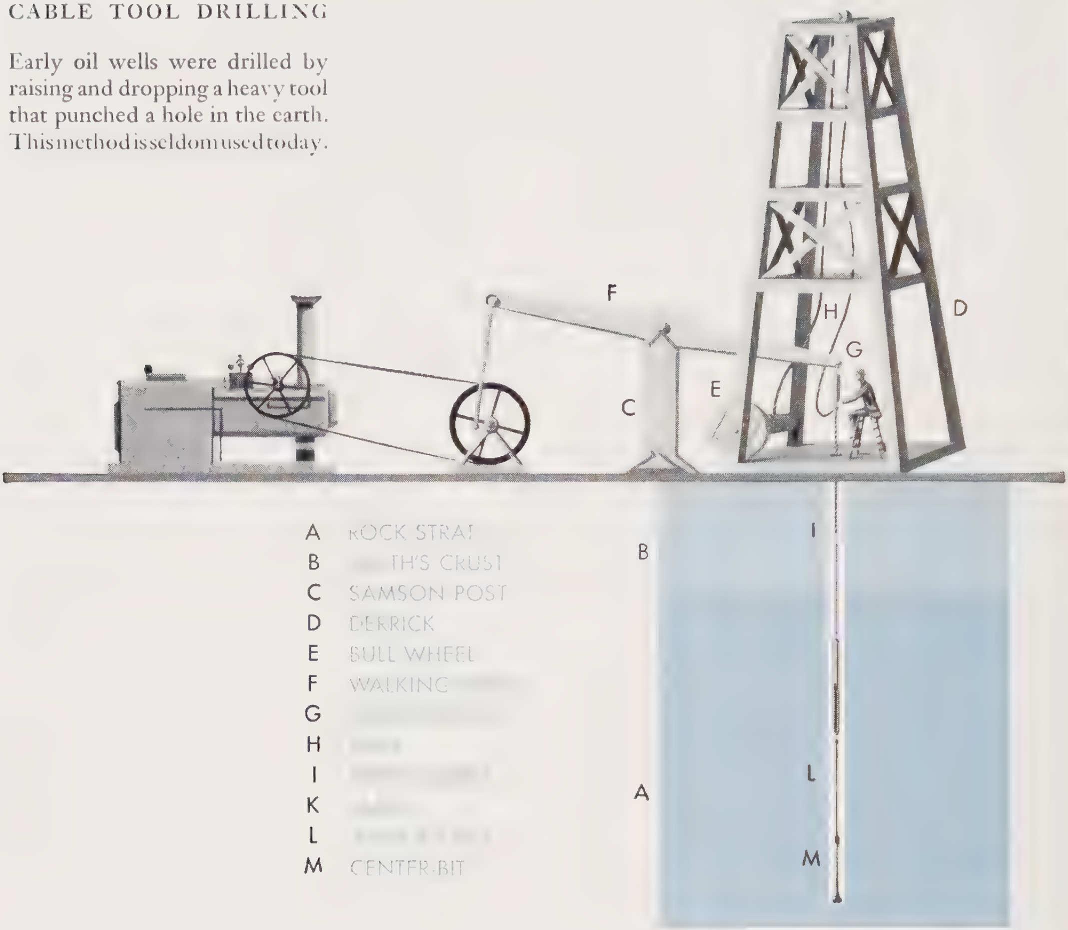
As the hole was driven deeper into the earth, Drake had trouble with his fellow-stockholders, who did not share his conviction of success, and with cave-ins of the well. His method of solving the second problem was a major contribution to the art of drilling. He obtained sections of pipe and used them to line the well. As the drilling progressed, the pipe was driven deeper into the ground and prevented the sides of the hole from caving in. The use of *casing* to line oil wells is uniform practice today.

In August, 1859, after about two months of drilling, Drake's well struck oil at a depth of 69½ feet. The well flowed at a rate of fifteen to twenty barrels per day. With crude oil then bringing $20 per barrel, this was more than enough to repay the efforts of all connected with the venture. People flocked into the area to drill other wells and to share, if they were lucky, in this new wealth from the earth. Word of the phenomenal event at a small rural town in Pennsylvania spread throughout the world and stimulated

DRAKE'S WELL, 1861

CABLE TOOL DRILLING

Early oil wells were drilled by raising and dropping a heavy tool that punched a hole in the earth. This method is seldom used today.



similar efforts in many other places. Almost overnight the modern oil industry was born.

It is said that the practice then was to drill to about 69 feet—the depth of Drake's well—and to abandon the hole if oil had not been found. However, it was soon discovered that oil might be found farther down. In the United States, the wave of oil-seeking spread westward across the continent. As time went on, discoveries were made in Ohio, Oklahoma, California, Texas, and other states.

Wherever new oil strikes were made, there was great excitement and wild activity. Towns sprang up. There was feverish bidding for the purchase or lease of land. Large amounts of money were made almost overnight—and frequently lost as quickly. Subsidiary businesses, such as the making of barrels to hold oil and transporting it by horse-drawn drays, were created.

With true Yankee enterprise, American merchants not only refined the crude and sold its products at home but, within two years after Drake's discovery, were conducting a brisk export trade in barreled oil sent by sailing ship to Europe and other parts of the globe. American drillers, because of their greater experience, were frequently hired for large fees to explore for oil in other lands. Thus, the oil industry from the outset was given an American stamp which it has retained through the years.

American oilmen, some people say, have "a nose for oil." They discovered most of the world's present-day oil fields. In some cases, particularly in the Middle East, they found oil in lands which other exploring companies had searched and abandoned as worthless.

Sometimes the hardships that must be overcome to find oil, bring it to the surface, and transport it to its destination are almost comparable to the rigors of military campaigns. In Bolivia, for example, Americans explored 18,000 square miles of steaming tropical wilderness, inhabited only by animals, poisonous snakes, and unfriendly natives. They hacked roads a thousand miles through jungles and over mountains. They made, in all, thirty-five separate expeditions, costing millions of dollars, before discovering oil.

The same conditions were encountered in Colombia, in parts of Venezuela, and in the Netherlands East Indies. Another set of conditions, equally arduous, had to be overcome in the deserts of Arabia, where the Bedouin tribesmen con-

OIL TOWN, 1927

sidered American explorers fair game for kidnaping forays.

Early oilmen usually sank their wells where there were clear indications of oil—such as surface seepages. Frequently, however, they drilled simply by hunch. On occasion, they fell back on some of the trappings of superstition such as divining rods, or on contraptions of varying complexity called "doodle bugs." These were supposedly capable of detecting underground oil.

Meanwhile, accumulating experience was forming a foundation for the scientific study of how oil occurs in the earth. The composition and physical features of the earth had been the subject of man's curiosity from early times, and the science of geology had been developing for a long while. However, it was not until the turn of the present century that

OIL TOWN, 1947

enough was known about petroleum so that the two bodies of knowledge could be combined into the specialty of *petroleum geology*.

Modern techniques of exploring for oil make use of all our knowledge of oil's origin and of how it accumulated within certain portions of the earth's crust. We believe, for example, that when oil was formed in the buried sediments of ancient seas, it existed first in the form of droplets widely dispersed in the rock layers. With it in the rock, there was also salt water. Along with the oil, gas had been formed from the same organic matter. A mixture of oil, gas, and water will not stay mixed because the oil is lighter than the water, and the gas is lighter than both. The three fluids tend to "sort themselves out." The oil and gas work their way above the

water contained in the rock layers, seeping through porous rock toward the surface of the earth as persistently as a stick will bob to the surface of a pond.

Much oil and gas came to the surface of the earth ages ago and was lost. But not all escaped—much was caught in subterranean *traps* formed by the buckling and folding of the earth in early geologic time. These traps are of three major kinds. All of them consist of layers of porous rock covered by layers of nonporous rock.

For example, porous rock into which oil originally moved may have been folded upward, producing a subterranean formation shaped like an upside-down bowl or saucer. Oil and gas may collect at the top of such an inverted bowl and be kept from escaping by an overlying nonporous layer. This kind of trap is known as an *anticline*.

A second kind of oil trap is formed at a fault, or break in layers of rock. The rock on one side of the break has slipped up or down so that an uptilted end of a porous layer is thrust against a nonporous layer and thereby sealed.

In a third type of oil trap, buried sandstone that may once have been an old beach tapers off like a wedge, ending between layers of rock that are not porous. Here the oil moves through the sandstone until it can go no farther and collects to form an oil field. This type of accumulation is called a *stratigraphic trap*.

It can be seen, therefore, that oil is not everywhere underground as air is above ground. It accumulates only here and there in traps. The petroleum geologist does not look for oil itself but tries to find these traps. They may lie near the surface or miles deep. They may be of almost any size or shape.

The geologist exploring for oil patiently scans the countryside. He studies aerial photos for differences in terrain or foliage that will indicate differences in the soil and rocks. He looks for outcrops—layers of rock that stick out of their

SUBTERRANEAN TRAPS

Oil is found in three kinds of "traps," called (left to right) "faults," "anticlines," and "stratigraphic."

mantle of soil—an activity which has earned the geologist the nickname of "rock hound." He may find his best clues in the canyons and gullies cut by rivers and streams. These gashes in the earth often expose layers of rock which the geologist can read like pages of time past. They also tell him which way the layers of rock are sloping, and this is important because he is always looking for tilted structures in which oil may have been trapped.

The "rock hound" examines exposed strata for fossils—the shells and bones of the tiny sea creatures still preserved in the rock that was once the silt floor of the ocean. Some are so small that a microscope must be used to see them. Others may be as big as a man's head. Paleontologists—the men who make a scientific study of fossils—have classified hundreds of thousands of these remains of plants and animals. They are an important clue to the period in which the rock was formed and reveal whether it is the type in which oil is likely to occur.

The amount of information that can be gained from the study of the surface is limited, however, so other sciences are used by the explorers for oil. Various devices have been developed with which petroleum scientists can probe beneath the earth to learn about the shape and nature of the rocks buried below. Chief among these devices are the gravity meter, the magnetometer, and the seismograph. The science of using them and interpreting their findings is known as *geophysics.*

These instruments do not tell whether oil exists at a certain place; they merely help to indicate places where conditions are favorable for its presence.

The gravity meter

The gravity meter is an instrument for measuring the gravitational force of the earth. This is not the same at all points. Heavy and dense rocks exert a greater pull than rocks which are lighter and less dense. And rocks near the surface have a greater pull than rocks of the same kind and size at greater depth. For instance, a man standing over a deeply buried mass of granite weighs a shade less than if the granite is near the surface. He weighs a little more when standing over granite than when standing over sandstone. With the gravity meter, the geophysicist obtains clues as to both the nature and the depth of the rocks beneath various points on the earth's surface.

The magnetometer

The magnetometer measures the strength of the earth's magnetic field, which is the force that causes compasses to point north. This force is also affected by the nature and depth of hidden rock layers.

The seismograph

The most widely used device for studying deeply buried strata is the seismograph—an instrument for measuring and timing vibrations of the earth. It is the same kind of instru-

GRAVITY METER

Gravity meters measure the "pull" of hidden rocks far below the surface of the earth.

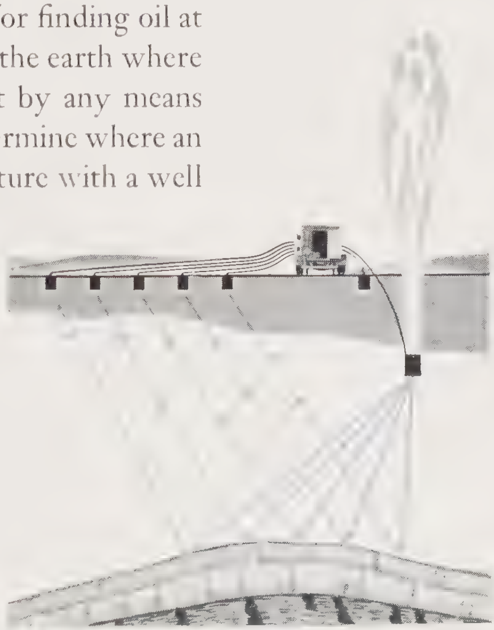
MAGNETOMETER

Magnetic variations charted with a magnetometer are used to help find oil.

SEISMOGRAPH

ment that is used for detecting earthquakes, sometimes at a distance of thousands of miles, and is so sensitive that it can record an ant's footsteps. When oil hunters use it, they make a small earthquake by drilling a hole in the ground and setting off a dynamite blast at the bottom. The explosion sets up waves in the earth much like waves in a pond when a stone is thrown into it. These waves are reflected more strongly from hard rocks than from less hard ones. They return to the surface from shallow strata in a shorter time than from deeper strata. And their reflections will vary in other ways, depending upon the nature and slope of the rock layers. The reflections are recorded by the seismograph as wavy lines on a strip of photographically treated paper. This record shows the time-difference between the dynamite shock and the echo at a number of different points. Such data, taken over a wide area, help find the folds and faults of rock strata which may be traps for underground oil.

The geologist, geophysicist, paleontologist, and their associated scientists have improved the odds for finding oil at the great depths and over the wide areas of the earth where it is now sought. However, they have not by any means made oil finding a sure thing. They can determine where an oil field *may* be, but only tapping the structure with a well will prove whether oil is actually there.



(Left) A seismograph crew explodes dynamite to make a small earthquake. (Right) The shock waves are reflected from buried rock layers and are recorded by sensitive instruments on the surface.

4

Drilling the Wells

Oil searchers have much in common with farmers and fishermen. They are men who enter a contest with nature to provide products that will meet human needs. They are all trying to harvest a crop—from the surface of the earth, from beneath it, or from the depths of the seas. How successful they are is a gamble. Sometimes a lot of work and money brings no return.

But the oilman has one problem that does not bother the farmer. Before the oilman can harvest his crop he has to find it. Even the fisherman does not have so difficult a problem in this respect, for locating a school of fish is simple compared with finding an oil field.

The oil industry's hunt for new fields is a search that never ends. New petroleum must constantly be found to replace that which has been used. Only in this way can the oil companies maintain their crude reserves and keep sending raw material to the refineries and products to market.

The oil hunters are comparable not only to farmers and fishermen; in some ways they resemble detectives. The nee-

dle in the haystack could not be harder to find than oil in previously untested territories. Drilling a well is an expensive job, and the objective of all the oil hunters' studies is to increase the chances that a particular well will strike oil and thus bring a return on the time and money invested in it. Even with the great advances in scientific methods for locating oil traps, however, the chances of a particular well striking oil in new territory are very slim. For example, in 1947 an important oil field was discovered near Leduc in the Province of Alberta, Canada. But before it was found thirty years had been spent in exploration and 133 wells had been drilled. The sum of the depth of those wells was over 100 miles, and they cost many millions of dollars.

The clues collected by the scientists in the oil industry are carefully compared and studied. They are discussed both with field workers and with executives at the home office of the oil company. Factors of expense and of the risk involved in drilling in one location as compared with some other location are thoroughly considered. Finally, a decision is reached and a precise spot is selected to *spud in*. This is the term drillers use for the first bite their tools take in the earth.

There are two methods of drilling a well: cable tool and rotary. No matter which is used, a derrick is built as a convenient support for the many pieces of equipment that must be lowered into the well. "Derrick," incidentally, was the name of a famous hangman of the seventeenth century. Oil derricks are tapering towers, usually of open steel framework, and may be as tall as a twenty-story building.

Cable tool drilling is the older method. It was used by Colonel Drake and, before that, it had been known for thousands of years. The principle was used by the Chinese to dig water wells centuries ago. A hole is punched into the earth by repeatedly lifting and dropping a heavy cutting tool hung from a cable and called a *bit*.

Today, however, more than 90 per cent of all wells are drilled by the rotary method. Rotary drilling bores a hole into the earth much as a carpenter bores a hole with a brace and bit into a piece of wood. In the middle of the derrick floor there is a horizontal steel turntable which is rotated by machinery. This rotary table grips and turns a pipe extending through it downward into the earth. At the lower end of the pipe there is fastened a bit.

DRILLING BITS

Three kinds of bit shown are (left to right) roller bit, diamond drill core bit, and fish-tail bit.

There are several kinds of bit. A common type, used to drill hard formations, has toothed rollers at the bottom. When the bit is turned, these rollers grind into the rock.

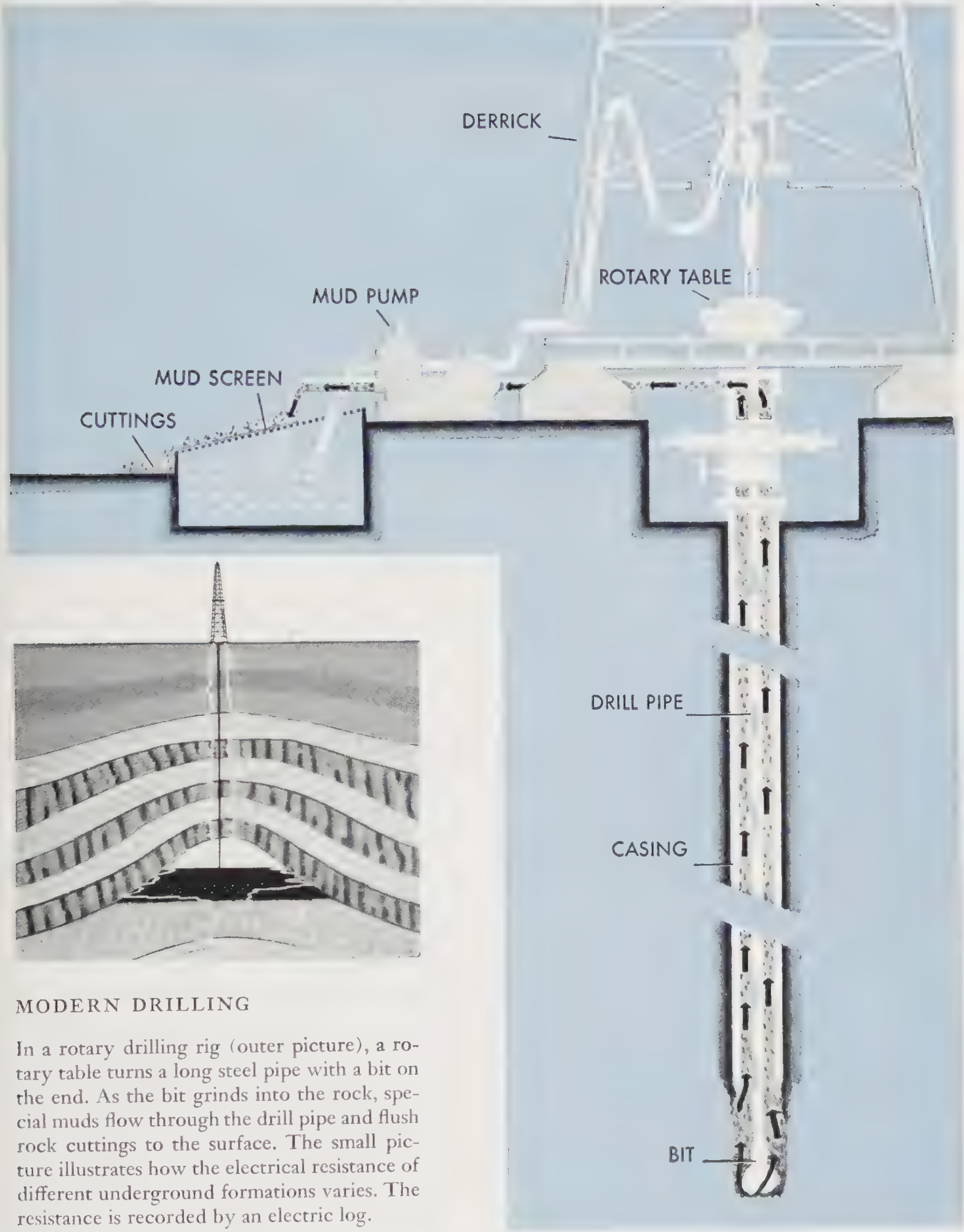
As the drill chews its way farther and farther down, more drill pipe is attached to it at the upper end. Although drill pipe is usually 4½ inches or 5 inches in diameter, as section after section is added, it becomes almost as flexible as a thin steel rod. Controlling it under these conditions and keeping the hole straight require great skill.

During the drilling a mixture of water, special clays, and chemicals, known as drilling mud, is pumped down through the hollow drill pipe and circulates back to the surface in the space between the outside of the pipe and the walls of the hole. This mud serves several purposes. It lubricates and cools the bit; it flushes the rock cuttings to the surface; and it plasters the side of the hole to help prevent cave-ins until the drillers are ready to test the well. The mud also holds back any gas, oil, or water which might tend to flow into the hole. If any of these fluids gets out of control, there is a blowout. Great care is taken to prevent such accidents.

In rotary drilling, one chief function of the towering derrick is to support the pulleys over which pass the cables that raise and lower the drill pipe. When the drilling bit becomes dull, it is necessary to pull the drill pipe out of the hole in order to put on a new bit. Pulling the pipe, changing the bit, and running the pipe down the hole again are hard work. It may be necessary to stack in the derrick two or three miles of pipe in 90-foot lengths, just to put on a new bit which may, in very hard formations, drill only a few feet before it in turn becomes dull.

As the hole is deepened, it is lined with successive lengths or *strings* of steel pipe called casing. Each string of casing slides down inside the previous one and extends all the way to the surface. The result is something like a telescope with the large end at the top and the small end at the bottom of the hole. Cement is pumped between these successive strings and seals against any leakage of oil, gas, or water.

During the course of drilling, information on the rocks penetrated is obtained by various means. Rock cuttings brought up by drilling mud as it returns to the surface are examined to determine the kind of strata the bit is chewing through. Cylindrical sections may also be cut out of the rock by means of a special bit. These samples are called



MODERN DRILLING

In a rotary drilling rig (outer picture), a rotary table turns a long steel pipe with a bit on the end. As the bit grinds into the rock, special muds flow through the drill pipe and flush rock cuttings to the surface. The small picture illustrates how the electrical resistance of different underground formations varies. The resistance is recorded by an electric log.

REPLACING A DRILL BIT (ABOVE) SAMPLE CORES (BELOW)

cores and are taken to the laboratories for study. Another method is to lower an electric logging instrument into the hole. This instrument measures the resistance of the exposed rock layers to an electric current. The resistance varies with the nature of the rock and also with the amounts of oil, gas, and water it contains. By recording these resistances on a strip of paper, it is possible to get a kind of picture of the inside of the well.

Oil in underground traps is usually under pressure, with water below it and gas above it. When the reservoir is tapped by a well, the pressure tends to move the oil up to the surface just as gas in a seltzer bottle shoots the water out through the tube of the bottle with considerable force. In new fields the pressure usually is sufficient to force oil up the well to the surface. This action is called natural flow.

When the oil-bearing rock is reached, the drill is removed while the mud holds back the flow. The final string of casing is set, and a pipe called tubing is lowered into the well. It is through this tubing that the oil flows out. At the surface end of the tubing a system of valves and controls known as a "Christmas tree" is fastened. These valves control the flow of oil up the tubing and into surface pipes leading to storage tanks. After the tubing has been set in place, and the "Christmas tree" connected, the derrick may be removed. The well is still there and the oil keeps on flowing, but only a few valves are left to mark the spot. Often they are so inconspicuous that the casual observer overlooks them entirely. The derrick which was used in the drilling may be re-erected somewhere else.

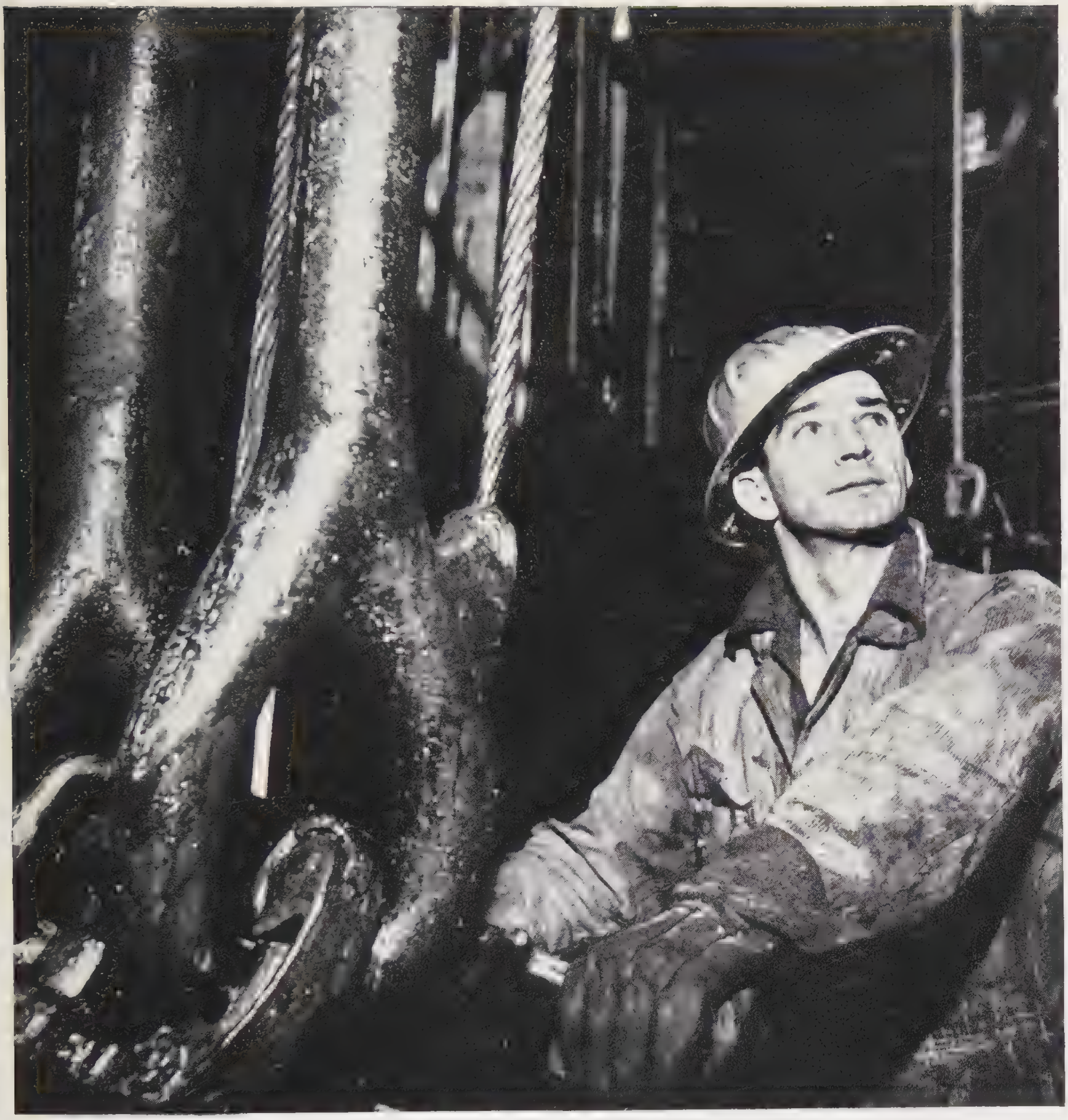
Although great pains normally are taken to drill wells in a straight path, it is possible to slant them away from a vertical line when necessary. This procedure is known as directional drilling. It involves fastening in the well a special fitting, so shaped that it will deflect the drill from the path it

(Opposite—top) ...Strong arms and a light touch are needed to change bits. (Bottom) Cores are tested in the laboratory.

has been following and will start it boring in a new direction.

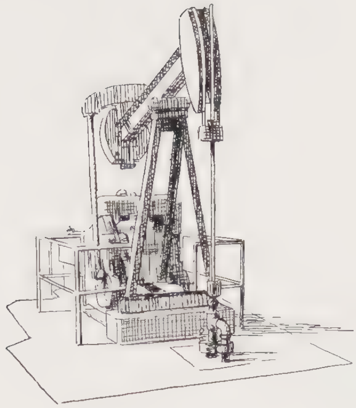
Directional drilling is often used to tap oil fields under water from a well which was spudded in on the dry land. Another use is to bring a burning or wildly gushing well under control. In this case another well may be drilled from a safe distance and directed so it will intersect the wild or burning well many feet below the surface. The directional well enables the oilmen to pump heavy mud into the wild well so that the flow can be controlled or stopped completely.

The art of drilling has progressed greatly since the early days, under the spur of need to go deeper for new resources. Today, with oil wells being driven regularly two or three miles down, much engineering study and research have been done in an effort to develop new and better methods of penetrating the earth. Among the methods currently under study are several in which a drilling bit would be rotated by a motor at the bottom of the well. Even the use of flame and heat as a possible means of boring through rock is under study. While these particular methods may not be the ones finally used to solve the present problems of deep drilling, the industry is confident that it will be able to continue its record of finding new techniques for developing our oil resources.



DRILLER

A typical hard-working member of a drilling crew in action on the derrick floor. This particular man was a member of the crew at the Leduc discovery well in the new field in Alberta, Canada.



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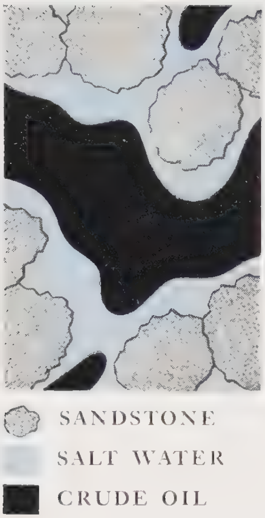
In the early days of the industry, relatively little was known about how oil occurs or how it behaves in the underground reservoir. As a result, production was often wasteful. Oilmen learned, however, that there was much more to producing oil than just drilling wells. Today, experience and scientific developments have vastly increased the amount of oil which can be obtained from a particular field.

Underground deposits of petroleum are sometimes referred to as *pools*. This is perhaps an unfortunate term since it creates a mental picture of a sort of subterranean lake. Actually, as we have seen, oil usually occurs in strata of rock which are just as solid as the limestone or sandstone used to face a building. In the conversations of oilmen oil-bearing rock strata are often spoken of as *oil sands*. The oil lies in the minute pores of these rocks in much the same way as the stone of a building's façade may be saturated with water after a prolonged rain. Obviously, oil can seep through these rocks only at a very slow rate.

However, water and gas move through the rocks more

easily than oil. Therefore, if the pressure at the bottom of a well is lowered suddenly by letting the oil come out too fast, the gas in the reservoir will come down from above and the water up from beneath before the oil can move in evenly from the sides.

Water under the oil, instead of pressing evenly over the bottom of the whole field, may come up in a cone directly under the well. In this case it might by-pass and seal off great areas of productive formation. The well would soon produce more gas or water than oil, and large quantities of oil would be lost.



If oil-bearing sandstone were greatly magnified, it would look like this, with the crude oil and the salt water trapped in the rock's tiny pores.

In the early days, these factors were not understood, and new wells were allowed to gush freely until the natural pressure was spent and the oilmen could pump the well. Modern oilmen use great care to prevent gushers because they are wasteful. Today gushers rarely occur and then only by accident.

When oil flow is controlled, through a choke valve at the top of the well, the water underneath the oil and the gas above it press evenly over the whole layer of oil, and it flows in from the sides of the reservoir to the hole.

The forces which push oil through underground rocks are known as drives, and there are three major types:

Dissolved-gas drive

Here, there is no gas above the oil or water below it, but the oil contains gas dissolved in it. The pressure of this gas, seeking to expand, pushes the oil through the rocks and to the wells. Oil recovery is low with this type of drive.

Gas-cap drive

In addition to gas dissolved in the oil, there is a large amount of gas above it. This gas cap expands into the oil sand and aids oil recovery.

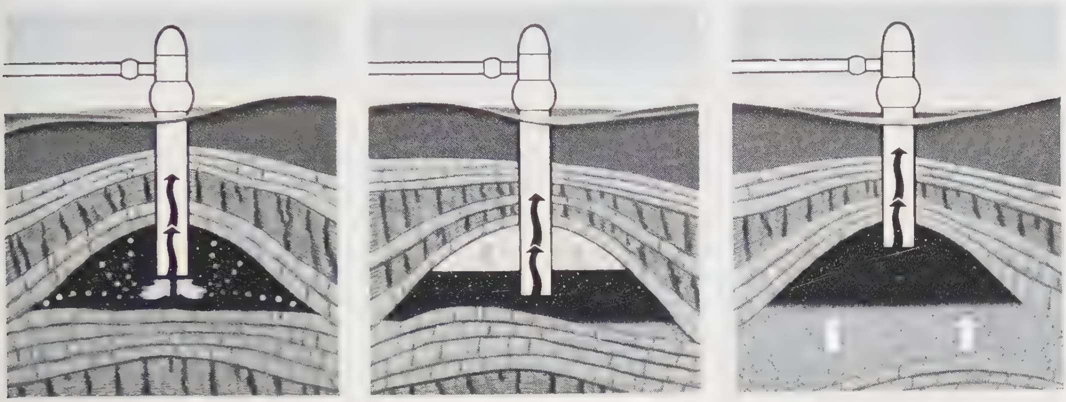
Water drive

A large quantity of water lies below the oil and gas. The

water moves into the oil-bearing rock and flushes the oil ahead of it.

When a new field is opened, the petroleum engineer wants to know as quickly as possible which of these various drives, or what combination of them, will provide the energy to move the oil to the wells.

TYPES OF DRIVE THAT PUSH OIL



Dissolved-gas drive. Expanding gas moves the oil.

Gas-cap drive. A layer of gas pushes down on the oil.

Water drive. Water below the oil forces it upward.

Study of these factors has actually begun before the well is sunk. The data provided by geology and geophysics indicate in a general way the type of structure which it is planned to tap, and may provide some clues to the kind of drive that may be encountered.

With the drilling of the first well, additional information begins to collect in the scientists' notebooks. When several wells have been sunk, even though some may be dry holes with no oil at the bottom, the picture of the reservoir begins to take shape. Samples of the underground strata brought up by the core bits will tell how porous the oil sand is.

Special instruments are used to measure the original *bottom hole* pressure in a reservoir, and further readings are

EARLY OIL FIELD

The first oilmen believed they could obtain more oil by close spacing. Today we know that as much or more can be recovered by placing wells farther apart.

MODERN FIELD SHOWING WIDE WELL SPACING

taken at regular intervals over a field's life. Samples of the oil and gas are obtained by a device which is lowered to the bottom of the well and which brings up some of the reservoir fluid under full pressure. Such samples are analyzed in the laboratory, and various characteristics of the oil and gas are thus determined.

In addition to observing the field itself, the modern petroleum engineer uses scale models which are constructed to simulate the conditions of rock porosity, oil viscosity, and pressure in the field being developed. By this means, and with the use of electrical computing machines to solve the complex mathematical formulas involved, he may determine in a matter of days how the field would behave over a period of years under different producing methods.

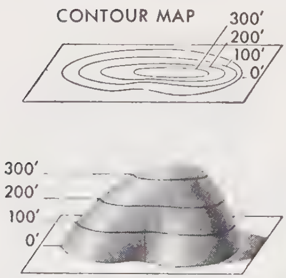
In the industry's early days, operators had a theory that more wells meant more oil. Wells were drilled so closely that their derricks almost touched. Today, oilmen know that it is not only cheaper but more efficient to drill fewer wells. Many modern fields have only one well for each 40 acres, and spacing as wide as one well to 80 or even 160 acres is sometimes used.

As withdrawal in a field continues, underground pressure usually declines, even though at a controlled and anticipated rate. Often the pressure drops to a point where natural forces are no longer sufficient to bring up the oil, and the wells must then be pumped.

Sometimes wells cease to flow because the rock area around the bottom of the well becomes clogged with small particles of wax, asphalt, or other material. The oilman may then lower nitroglycerine into the well and explode it to open new channels through which the oil can flow. Or he may pump strong acids into the well to accomplish the same thing.

Although thirty or forty years ago oilmen thought that as

PEG MODEL OF AN OIL FIELD. Uprights indicate wells drilled.



much as three-fourths of the oil in a field might be unrecoverable, today the amount of oil left behind may be as little as 20 per cent in a very efficient field. Through modern conservation techniques, oilmen are getting more oil by taking less at a time.

Many old fields in which oil was left behind are reworked by modern techniques to obtain a second "crop." This is known as secondary recovery. Flooding with water is a

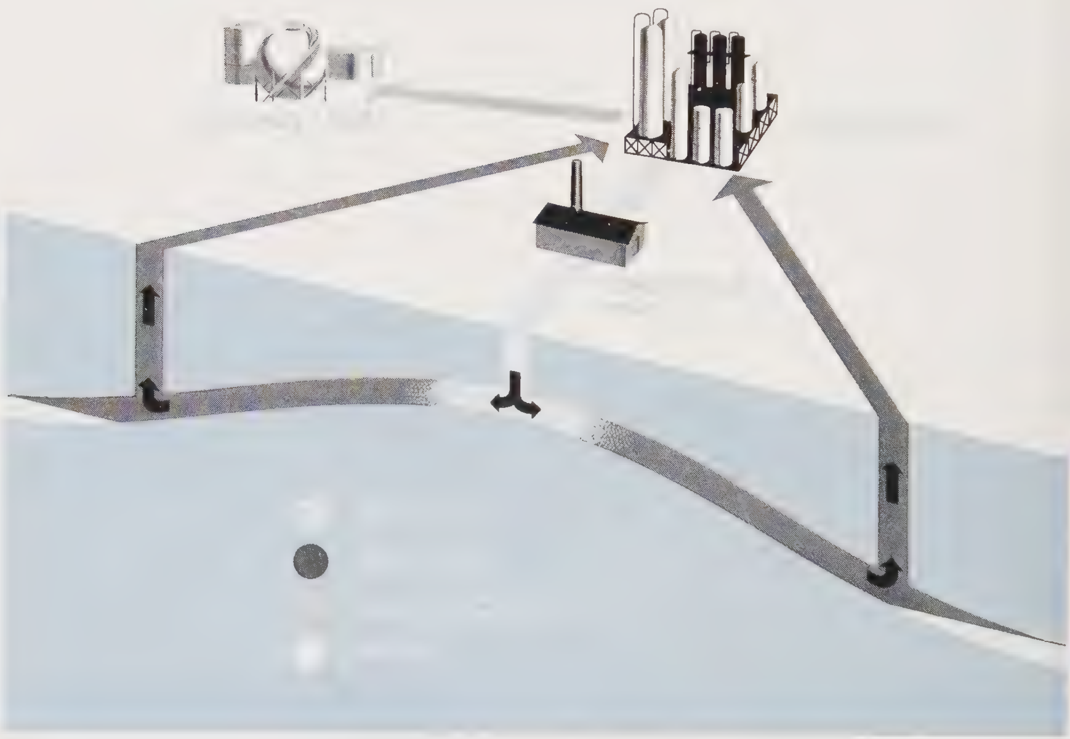
GAS STRIPPER

In this recycling plant natural gas is stripped of its gasoline content and then put back in the earth to help recover more oil.

common means of secondary recovery. By this process, water is pumped into the oil sand and flushes the oil ahead of it to the wells. Injecting natural gas back into the producing formation is another way of accomplishing the same thing.

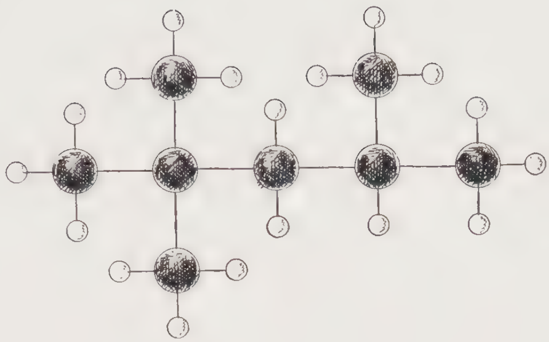
The oil and gas from a well reach the surface in a frothy mixture which is routed through the valves of the "Christmas tree" to tanks where the gas is separated and the oil sent on to storage. Any liquids remaining in the gas are removed

in *natural gasoline* plants, and then the dry gas is utilized in various ways. Some of it may be burned to supply power needed in the oil field. Some may be pumped back into the reservoir to help maintain the pressure. The surplus will probably be sold to gas companies for transmission to cities for use as industrial and domestic fuel. In recent years natural gas has also become of increasing importance as a raw material in the manufacture of many chemicals.



CYCLING WITH GAS

In the diagram "wet" gas, rich in gasoline, flows from the two outside wells to a cycling plant, where liquid products are removed and piped to storage. The dry gas under pressure is pumped back into the dome structure to help recover more liquid products.



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Petroleum as it comes from the ground is not ready for use. It is merely a raw material, much as newly felled trees are raw materials for pieces of furniture. Crude oil must be put through a series of processes in order to be converted into the many hundreds of finished products that are derived from it. These processes are known collectively as refining.

The visitor to a large refinery passes through street after street bordered with close-ranked equipment of bewilderingly varied shapes—cylinders slender as minarets, squat cylinders, tanks like silvery mushrooms, latticed towers. These structures are vast machines, exposed to the elements, mounting skyward in a riot of geometric patterns. In them crude oil is cooked, squeezed, cooled, reheated, and mixed with assorted chemicals.

This assembly of giants seems strangely placid. Very few men are seen because most of the operations are highly mechanized. The furnaces, towers, condensers, and reactors show no motion, and only a deep pervading hum tells of the great work going on within them. In the offices and labora-

A MODERN REFINERY

PRESSURE TANKS

Spherical steel tanks are used to store gas under pressure. These, in a refinery in Texas, hold butadiene, a petroleum gas used in making synthetic rubber.

tories many men and women gather knowledge of the crude oils to be refined and the products to be made, and direct and supervise the many manufacturing processes.

All this equipment and skill are necessary because crude oils vary widely in physical properties. Some are thick and heavy; some almost as light and clear as gasoline. Some are black or brown; some green or yellow. They often contain sulfur. Crudes having a high sulfur content are known as *sour* crudes because of their odor, while those with low sulfur content are called *sweet*.

Even a particular kind and grade of crude oil is not a uniform material. Rather it is a complex chemical mixture made up of molecules of many different kinds.

Molecules are the infinitesimal building blocks of all substances on earth. They are themselves made up of atoms. The nature of various substances depends on the kinds of atoms in their molecules and the way these atoms are linked together. For example, when atoms of hydrogen and oxygen—both gases—are combined in one proportion, they form molecules of water, a liquid. Combined in another proportion, they form the molecules of hydrogen peroxide, a quite different liquid.

All the molecules of petroleum contain the same elements —atoms of hydrogen and atoms of carbon. So oil and its various products are classified as "hydrocarbons."

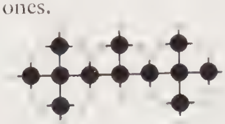
The molecules in crude oil, however, contain varying numbers of hydrogen and carbon atoms arranged in widely differing patterns. Some of the molecules contain a large number of atoms. Those with many carbon atoms make up the thicker and heavier components of petroleum, like asphalt. Others with relatively few atoms make up the lighter and more volatile components, like gasoline.

The first step in refining is *distillation*, which roughly separates the molecules in crude oil according to their size and

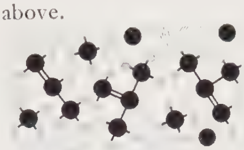
Petroleum is made up of
● Carbon
| Hydrogen

They combine to make very simple molecules

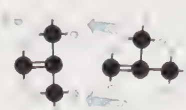
and also very complex ones.



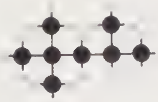
Petroleum products such as fuel oil contain molecules like the one shown above.



When the oil is cracked, this complex molecule is broken into many smaller parts.



The parts are then fitted back together in many new ways...



...to make new products.

weight. The process can be thought of as taking a barrel of gravel containing stones of many different sizes and running it through a series of screens to sift out the small ones, the next larger, and so on, up to the very largest of all. As applied to a barrel of crude oil, this sort of process "sifts out" such things as gas, gasoline, kerosene, home heating oil, lubricating oils, heavy fuel oils, and asphalt.

In modern distillation, crude oil is run through coils of pipe lining a large brick furnace, the interior of which is white hot with flame. After having been heated to about 800° F., the crude enters the bottom of a tall cylindrical steel container known as a *fractionating tower*. There, released from the confinement of the pipes in which it has been heated, all but its heaviest portions flash into vapor.

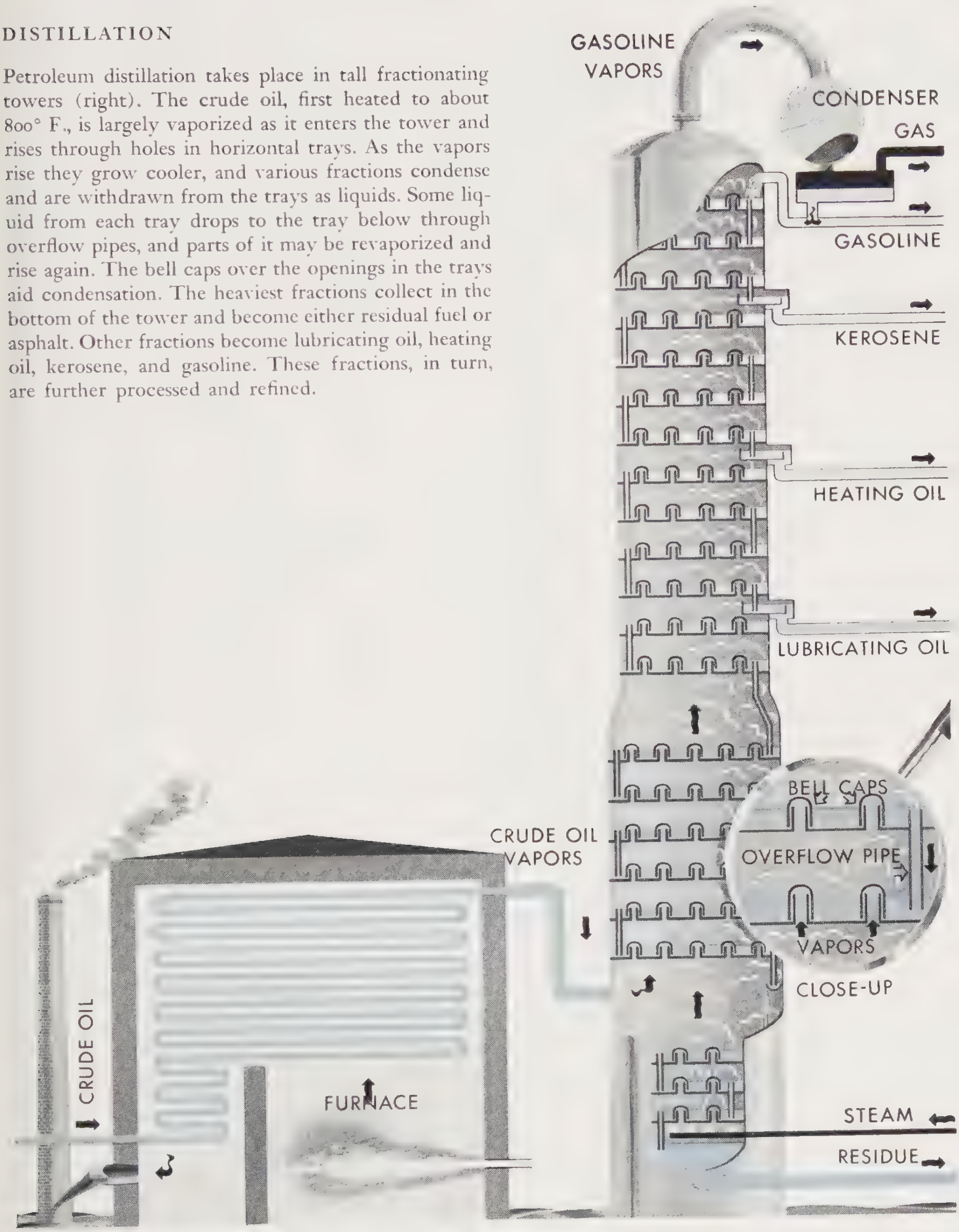
The various components of crude oil have different boiling points—that is, they change from liquid to vapor or condense back from vapor to liquid at different temperatures. By taking advantage of this fact it is possible to separate the oil into its different *fractions* or *cuts*.

The fractionating tower contains a number of perforated horizontal trays set one above the other throughout its height. Those near the bottom, where the heated oil is introduced, are hottest, while those above are successively cooler. As the petroleum vapors rise in the tower they condense on the trays according to the temperature at which each becomes a liquid again.

Gasoline, the quickest boiling fraction of the crude, begins to collect in the top trays at a temperature of about 100° F. Kerosene begins to condense a little lower down at a temperature of about 300° F. Heating oil begins to condense at about 500° F. Residual oils collect at the very bottom of the tower. Each component of the crude can thus be drawn off from the tower at a different level, and sent separately to further refining processes to make it ready for use.

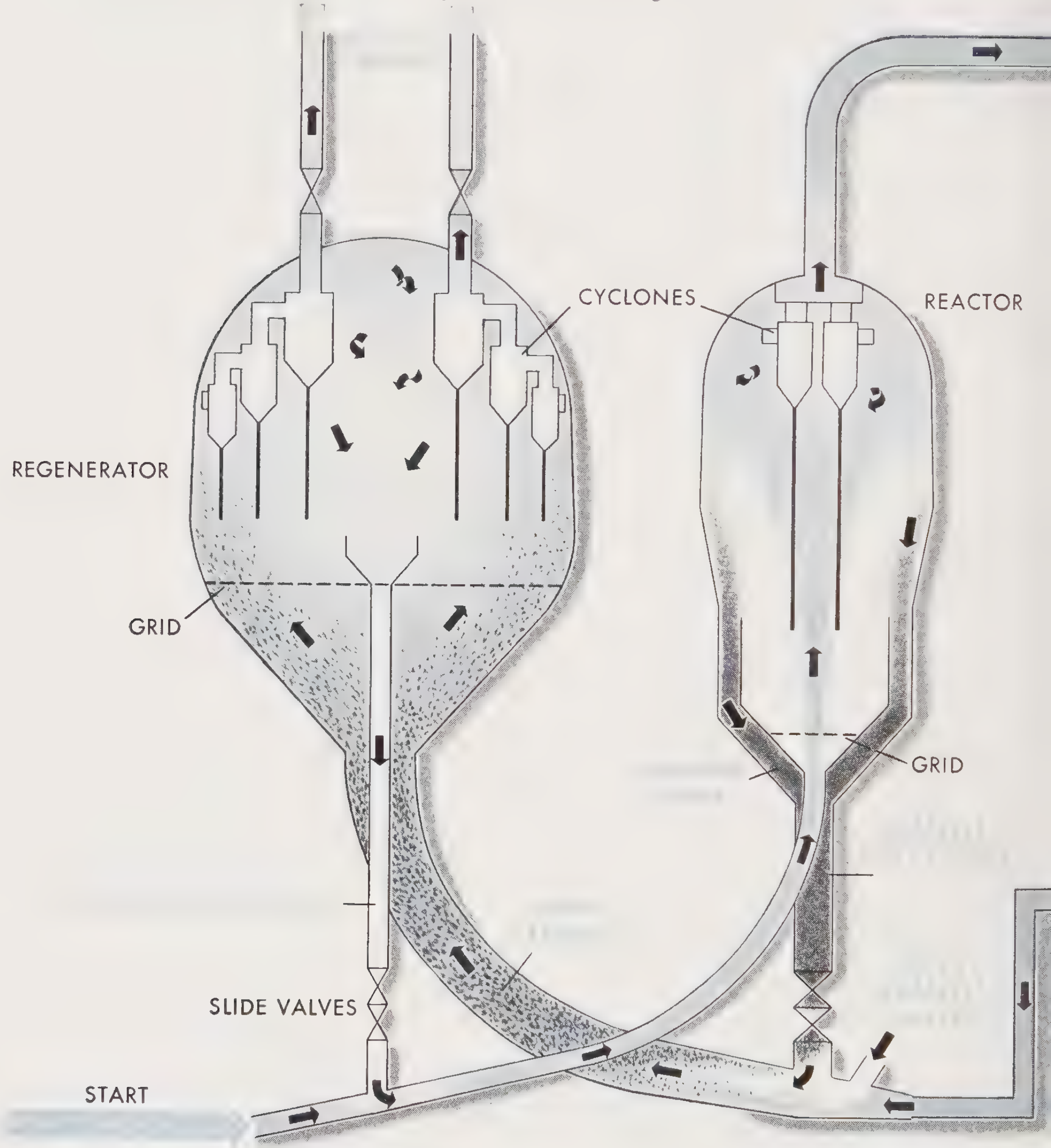
DISTILLATION

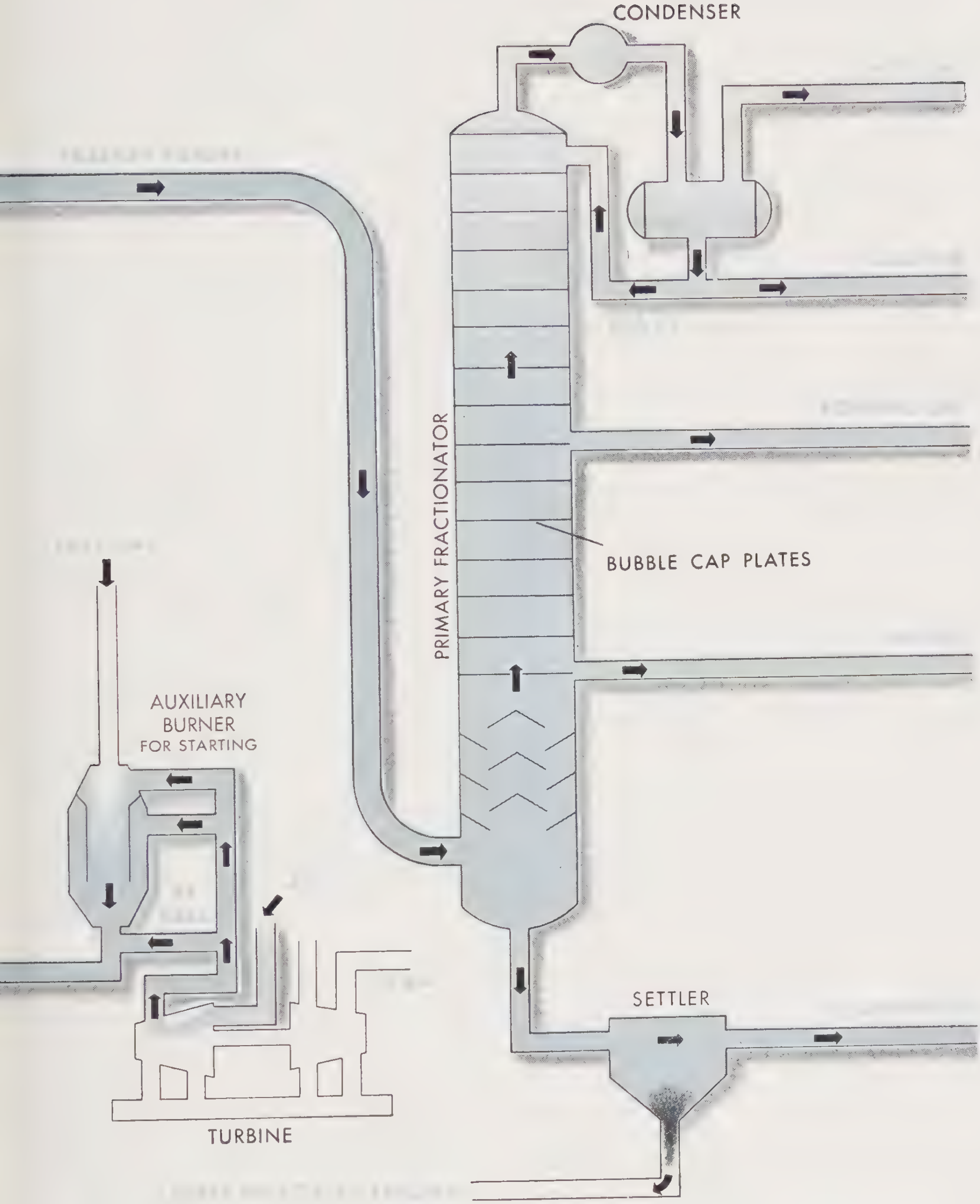
Petroleum distillation takes place in tall fractionating towers (right). The crude oil, first heated to about 800° F., is largely vaporized as it enters the tower and rises through holes in horizontal trays. As the vapors rise they grow cooler, and various fractions condense and are withdrawn from the trays as liquids. Some liquid from each tray drops to the tray below through overflow pipes, and parts of it may be revaporized and rise again. The bell caps over the openings in the trays aid condensation. The heaviest fractions collect in the bottom of the tower and become either residual fuel or asphalt. Other fractions become lubricating oil, heating oil, kerosene, and gasoline. These fractions, in turn, are further processed and refined.



FLUID CATALYTIC CRACKING UNIT

The Fluid catalytic cracking process, diagrammed here, begins when oil vapor enters the system, picks up regenerated catalyst, and flows to the reactor, where cracking takes place. The cracked vapors then go to a fractionating tower for distillation, and used catalyst returns to the regenerator.




CONDENSER
PRIMARY FRACTIONATOR
BUBBLE CAP PLATES
AUXILIARY
BURNER
FOR STARTING
SETTLER
TURBINE

Distillation can separate crude oil into its fractions but it cannot get more of a particular fraction out of the crude than nature put there. And consumers' demands for different products are not necessarily in accord with the proportions nature followed in mixing petroleum's ingredients. For example, if we had to depend on the amount of gasoline naturally present in crude—about 20 per cent—we could not make nearly enough of it to run the automobiles now on the road.

Fortunately, at about the time when the growing use of automobiles began to skyrocket the need for gasoline, a process was discovered for getting more gasoline out of crude than is naturally there. This process is known as *cracking*.

Earlier we compared distillation to sifting out stones of different sizes from a barrel of gravel. Cracking is comparable to crushing some of the larger stones in order to get more small ones. Cracking amounts literally to breaking big molecules into little ones. The type of cracking which was first invented (and which is still used) employs only heat and pressure and is called *thermal cracking*. A later development was *catalytic cracking*.

A *catalyst* is a substance that causes other substances to change chemically without being changed itself. No one knows precisely why it works—only that it does. In the catalytic cracking of petroleum, the catalyst is a claylike material which may be in the form of lumps, pellets, grains, or superfine powder.

The newest and simplest form of catalytic cracking is known as the Fluid process. A Fluid "cat cracker" is an awesome but highly docile chemical machine, towering in some instances to great heights, with huge steel drums and a labyrinth of pipes standing exposed to the weather. It is apparently unattended but, in a control house at its base, a few men guide its operations and follow the progress of its work

by means of a great maze of dials and meters and gauges.

Although the cracker's exterior shows no movement, a veritable storm takes place inside its huge vessels. Vast quantities of vaporized oil, air, and powdered catalyst circulate at high temperatures through miles of pipe and reactors.

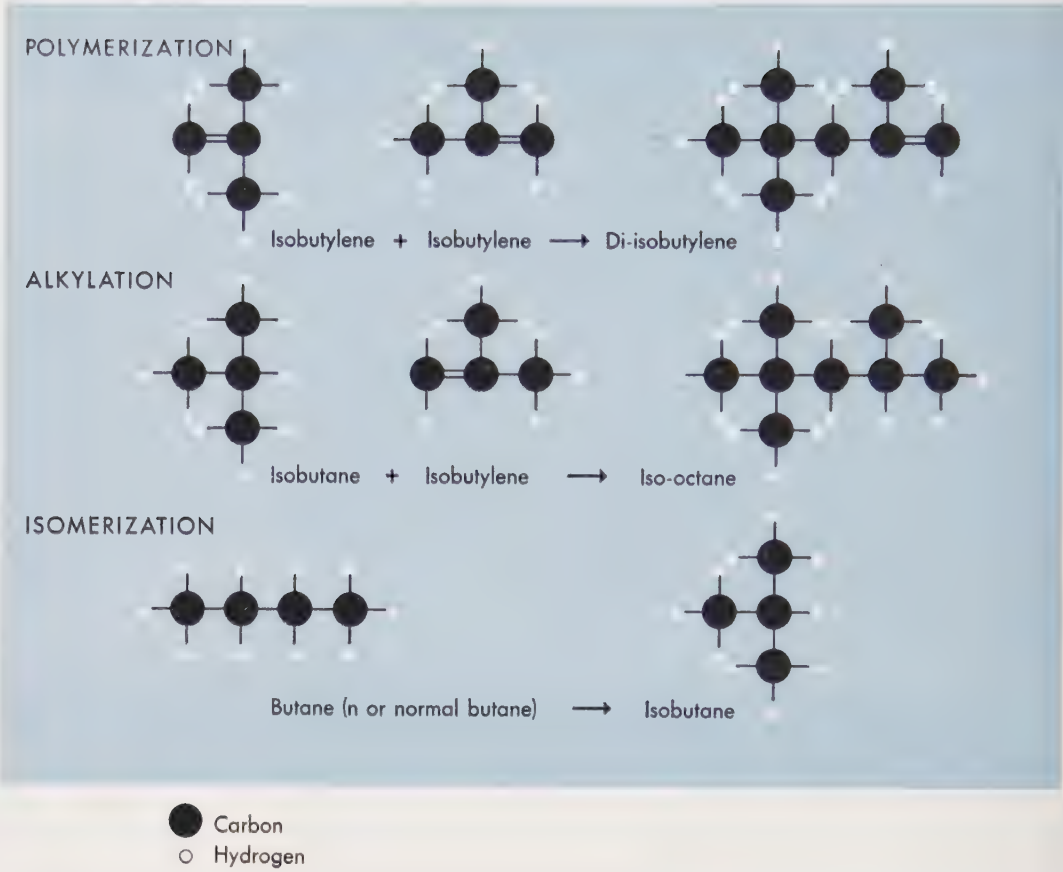
After being in use for a while, the fine grains of catalyst

CONTROL ROOM

become coated with carbon removed from the oil. The catalyst is then inactive. By being whirled into a regenerator where the carbon is burned off, however, the catalyst is reactivated and thus can be used over and over again.

These few men, in the control room of a catalytic cracking unit, operate the process by automatic instruments.

In the Fluid process the catalyst is so fine that, when agitated by blasts of air or other gases, it flows and can be con-



THREE IMPORTANT PROCESSES ILLUSTRATED

trolled by valves exactly as though it were a fluid. This method of handling a solid substance as if it were a fluid has been an extremely important forward step in oil refining. It was a vital factor in making America a tremendous producer of aviation gasoline and other petroleum products during the war. In addition, its use is being studied by other industries.

Cracking has made it possible to produce more than twice as much gasoline from a barrel of crude oil as can be made by simple distillation.

Petroleum refining employs many other processes for taking petroleum molecules apart, putting them together, and rearranging their atoms. The names of these processes are the terms of a modern alchemy. *Polymerization*, for instance, is the linking up of similar molecules to make larger ones. *Alkylation* is the linking up of dissimilar molecules. *Isomerization* is the alteration of a molecule so that the atoms, although still the same in number, are arranged differently.

Reforming, one of the newest refining methods for making high-octane gasoline, is a catalytic process in which some molecules are isomerized and others have hydrogen removed from them. In one version of reforming, the catalyst is handled in the fluidized state as in Fluid catalytic cracking.

Versatile equipment is needed to insure that all processes will continuously fit in with each other as the petroleum flows through a refinery, to permit modifications to accommodate crude oils of different kinds, and to turn out finished products to various and exacting specifications.

The petroleum products resulting from distillation or cracking, for example, require further refining to make them suitable for use. Concentrated sulfuric acid is a material which has been widely used for this purpose. A comparatively small amount of this powerful acid, added to oil, almost immediately coagulates impurities. The coagulated

GREASE

Grease-making is one of the oldest branches of the petroleum industry. Soap is part of the mixture.

material forms a sludge which is withdrawn from the bottom of the tanks in which the oil and acid are mixed.

In modern practice, however, sulfuric acid treatment has largely been replaced by other purification methods. For example, unrefined oil may be mixed with something called a "selective solvent." When allowed to stand without stirring, the mixture separates into two layers, just as oil and water separate from each other. The solvent layer contains the impurities, while the other layer consists of clean oil. A commonly used selective solvent is carbolic acid.

WAX

Paraffin wax, separated from oil, is molded in blocks. Excess wax is scraped from molds.

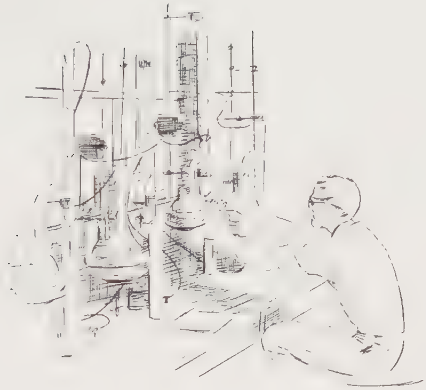
Some crude oils contain paraffin wax. In making lubricating oils from these crudes the wax is removed. This wax itself has many uses, but it is undesirable in a finished lubricating oil because it congeals when cold and prevents the oil from flowing properly. One way in which refineries separate the wax is by first diluting the oil with a solvent so the mixture will flow easily when cold, and then chilling the mixture. The wax forms like snowflakes throughout the oil and is removed.

In making grease, oil and other ingredients are blended

with different types of soaps in vats at carefully controlled temperatures.

Asphalt and road oil are among the residual fractions of petroleum. Most of the commercial asphalt has to be manufactured to meet various specifications. One method of manufacture is to blow air through the hot residue from the distillation of crude oil. The residue is thereby partially oxidized and thickened.

Thus it can be seen that thousands of products are made from crude oil. They include gases and highly volatile liquids, liquids thick as molasses, and solids. Some are made from start to finish in the oil industry's plants. Some are made by other manufacturers to whom the oil industry supplies raw materials. Final products range from explosives to fire preventives, from insect poisons to medicines, from crystal-clear toiletries to synthetic rubber, from oils to lubricate the machinery of ocean-going ships to other oils for the smallest and most delicate mechanisms. Every year the industry's scientists are finding new products which can be fashioned from petroleum.



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To retain present consumers and to win new ones in the face of competition, businessmen have turned more and more to scientists for help in making better products, improving services, or lowering prices. The joining of business and science has resulted in the field of industrial research.

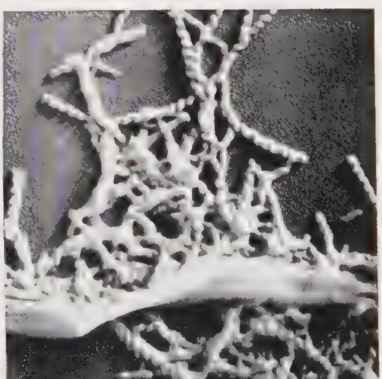
Modern industrial research began about forty years ago. It represents creative thinking implemented by a variety of specialized and complex machines. It is so organized that it gives free play to the talents of individuals, at the same time making possible the teamwork of many groups working on a given problem. In fact, this breaking of a problem into its segments and then applying mass effort to the solution of the parts is a chief characteristic of industrial research.

The petroleum industry has been one of the most advanced and persistent in applying science to business. The spectacular growth of the industry has undoubtedly been due in large degree to this fact.

All the major oil companies and many of the smaller ones have large numbers of chemists, physicists, engineers, and

ELECTRON MICROSCOPE

The electron microscope magnifies up to 100,000 diameters. The magnified substances at the right are grease and cuprene.



technicians on their staffs. They maintain extensive laboratories and spend large sums both for research within their own organizations and to underwrite scientific studies in universities.

During recent years researchers have discovered methods for obtaining from petroleum a large range and variety of new products, as well as products which previously were derived only from other raw materials. Synthetic rubbers, alcohols, fertilizers, solvents, insecticides, waxes, and numerous chemicals might be mentioned. However, petroleum research work has always been directed primarily to the development of better fuels and lubricants.

The metal plate in the lower jar has been rust-proofed, while that in the upper jar has not. Rust is beginning to form on the upper plate.

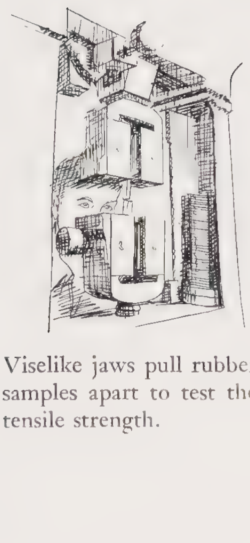
As we have already seen, crude oil is not made up of molecules of one size and shape, but is a mixture of different kinds of molecules. It is a kind of molecular treasure chest. Petroleum scientists have found out not only how to segregate the molecules but also how to take them apart and put them together in different patterns. Thus, they are able to "tailor-make" materials. They can turn out substances with just the qualities needed for a specific job. They can radically alter the natural characteristics of oil.

For instance, oil normally is inflammable. Yet the chemist actually makes a fireproofing agent from oil.

Oil floats on water—but petroleum scientists have developed a rust preventive which creeps under a film of water and lifts it from a metal surface. Wherever moisture is a destroyer of metal, whether it is a heavy tractor on the farm or a delicate scale in the laboratory, the rust preventive can be brought to the rescue.

Ordinarily, oil gets thick in cold weather and thinner as the temperature rises. But the petroleum scientists have developed oils for high-flying aircraft that change very slightly in "body" over temperatures ranging from the blazing heat of the desert to the bitter cold of the stratosphere.

SYNTHETIC RUBBER



Viselike jaws pull rubber samples apart to test the tensile strength.

Aviation gasoline developed by the oil industry is hardly gasoline at all in the sense that we used to know it. For this fuel is almost a completely synthetic product, tailor-made by an extensive rearrangement of petroleum molecules to provide characteristics desired. Scarcely a drop of modern aviation fuel exists in nature's petroleum, and this is becoming increasingly true of even high quality automotive gasoline. More and more, the need for high antiknock characteristics demands the application of science to provide the proper fuel desired.

Buna-S is the rubber-like synthetic used for tires. The oil industry does not itself make Buna-S but turns out most of the butadiene which is its main ingredient. It is now possible to have rubber in quantities previously undreamed of. What will be done with it? Among new uses of rubber are rubber springs to provide smoother auto rides, sponge rubber mattresses for greater bedtime comfort, sponge rubber for overstuffed furniture, greater use of rubber for noise control.

INSECTICIDE

Another synthetic rubber is Buna-N. Unlike natural rubber, Buna-N does not deteriorate when exposed to oils and acids. This makes it extremely useful for hoses, gaskets, flooring, shoes, gloves, and other articles that come in contact with those liquids.

A third rubber-from-oil, Butyl, is used for inner tubes. It holds air about ten times as well as natural rubber. Inner tubes made of it need to be inflated only three or four times a year, unless, of course, the valves are faulty. Butyl is also highly resistant to rips or tears, and consequently reduces the danger from blowouts. Modified Butyl may be developed into a superior material for tires.

Oil is either the vehicle or active ingredient of numerous sprays used in agriculture. Improved cattle sprays are a factor in keeping herds healthy and our milk supply pure. There are tree sprays to kill orchard pests, sprays that retard budding and thus guard against losses from late frosts, sprays that delay the fall of ripe fruit and thus keep it from bruis-

ing and rotting on the ground. There are even oil products which, when properly applied to fields of growing crops, kill weeds without harming the crops.

From oil comes a soap that lathers freely in cold, hard, or salt water; from oil is obtained a substance that protects indefinitely against fabric-destroying mildew. Also from oil come the raw materials for making such miracle fibers as nylon and Dacron.

Such chemicals as alcohols, ketones, and esters have been made from petroleum for some time. But various new processes have put into the chemists' hands methods of making in enormous quantities chemical "building blocks" capable of so many combinations and developments that their possibilities will be a challenge to technicians for generations to come.

Despite the large number of new or improved products that can be drawn from the treasure chest of petroleum, their manufacture calls for only a small fraction of our petroleum supply. For example, less than one-half of 1 per cent of the oil produced in this country could supply all the rubber our nation is now using; another fraction of 1 per cent would take care of our domestic alcohol requirements.

The importance of chemicals from oil lies not only in new products. Many chemical raw materials already known can be derived from oil in much greater quantities and at lower prices than before.

Through the co-ordinated efforts of research, development, and engineering groups in the oil industry, the average service station price of gasoline, without taxes, is lower today than it was thirty-five years ago. During the same period the average antiknock rating or octane number of gasoline has risen materially, with consequent advantage to the consumer in the form of improved car performance and economy of operation. Today's car would knock badly if it were

RAM-JET

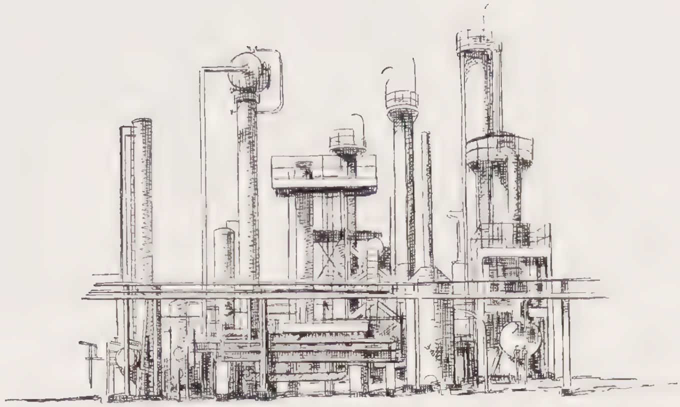
fueled with the gasoline of thirty-five years ago. Just as certainly it would spend much of its life in the repair shops if it were lubricated with the oils and greases of that time.

Fuels for special projects, like this "ram-jet" on the test stand, are being developed and tested in oil companies' laboratories.

Intensive work is in progress on high-octane motor gasolines and fuels for jet aircraft, a fast-growing field which involves totally different problems from those encountered with gasoline-powered piston-engine planes. Oil companies maintain liaison with engine manufacturers and the military services in order to provide satisfactory fuels not only for the automobile, diesel, jet, and turbine engines of today but also for those of the future.

WORLD CONSUMPTION OF PETROLEUM AND SOURCES OF SUPPLY, 1953 (EST

Total consumption
447,490,000 barrels
25 gallons per person
U.S.S.R. and Satellites
Total consumption
652,255,000 barrels
89 gallons per person
EE EUROPE
Total consumption
251,850,000 barrels
14 gallons per person
FREE ASIA
Total consumption
131,035,000 barrels
27 gallons per person
AFRICA
Total consumption
118,990,000 barrels
43 gallons per person
OCEANIA



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The special advantages of oil have resulted in the world's using constantly greater quantities of it. At the start of the present century world consumption of petroleum amounted to 160 million barrels a year. By 1953 annual consumption had jumped more than thirty-fold to 4,957,000,000 barrels. North America alone consumed about 65 per cent of that total.

The demand for liquid fuel in the United States has risen almost without interruption since the beginning of the industry. Even in the 1930's, at the low point of the depression, the demand for petroleum declined much less than the demand for most other products.

In this country, which for many years has used more oil than all the rest of the world together, consumption in 1938 was 1,137,000,000 barrels. The figure rose to 1,486,000,000 barrels in 1941, the last year before the nation's entry into the war; to 1,773,000,000 barrels in 1945, the year of peak wartime consumption; and to 2,785,000,000 barrels in 1953.

Although per capita consumption in the world as a whole

will not attain the present level of per capita consumption in the United States for many years, if ever, population growth and rising standards of living are greatly expanding oil consumption all over the globe.

Because of the tremendous present use of oil and the prospect of still greater use, people sometimes wonder whether we will have enough. At intervals, ever since the beginning of the industry, there have been predictions that supplies were about to run out. In 1919 some geologists proved, to their own satisfaction at least, that only 6 billion barrels of oil remained undiscovered beneath the surface of the United States. We have discovered 69 billion barrels in this country since then. A committee of Cabinet members reported to President Coolidge that the United States had only enough oil to last another six years. That was in 1926.

Some people think that we have enough oil in this country to last only a little longer than another decade. This figure is obtained by taking the figure for proved United States reserves—29 billion barrels—and dividing it by our annual production, which is about 2.3 billion barrels.

The trouble with the computation is that it assumes no new oil is going to be found in our country. The fact is, however, that we are still finding considerable quantities of oil, and geologists agree that there are still huge quantities undiscovered.

In the United States there are about 1.5 million square miles of land considered favorable for the finding of oil. Much of that area has not been actively explored, and new oil fields are still being found even in the intensely explored areas. Geophysics, combined with modern ability to examine the nature of the underground strata during drilling of a well, has permitted us to map our country, miles below the surface, with at least as much accuracy as marked the surface maps used by pioneers of an earlier day. And the

increasing ability to drive wells deeper increases the amount of oil which can be found.

In addition, some of the seaward area adjacent to the United States coast line—sometimes referred to as the *continental shelf*—contains oil. There are numerous physical difficulties in obtaining this oil—it is necessary, for example, to build drilling platforms several miles at sea, where they are exposed to the battering of waves and storms. But oil companies have already made remarkable progress in the

Far out in the Gulf of Mexico, seldom as calm as this, oilmen build derricks on steel piers to search for oil below.

OFFSHORE DRILLING ON CONTINENTAL SHELF

DESERT OIL

Under the sand dunes of Arabia lie some of the world's greatest oil reserves.

construction of islands from which drilling operations can be conducted, and continuation of this progress may add still further quantities to United States reserves.

The rest of the world has been much less explored for oil than the United States. The fact that the United States has one-fifth of the world's present proved reserves does not necessarily mean that this country has been more richly endowed with oil resources than other nations. It means merely that Americans have been more energetic in locating and developing their resources.

Proved reserves of crude oil in foreign lands are even now very large. Exclusive of Russia, the proved reserves outside

CANADIAN OIL

the United States totaled nearly 100 billion barrels at the end of 1953. Potential resources abroad are even larger.

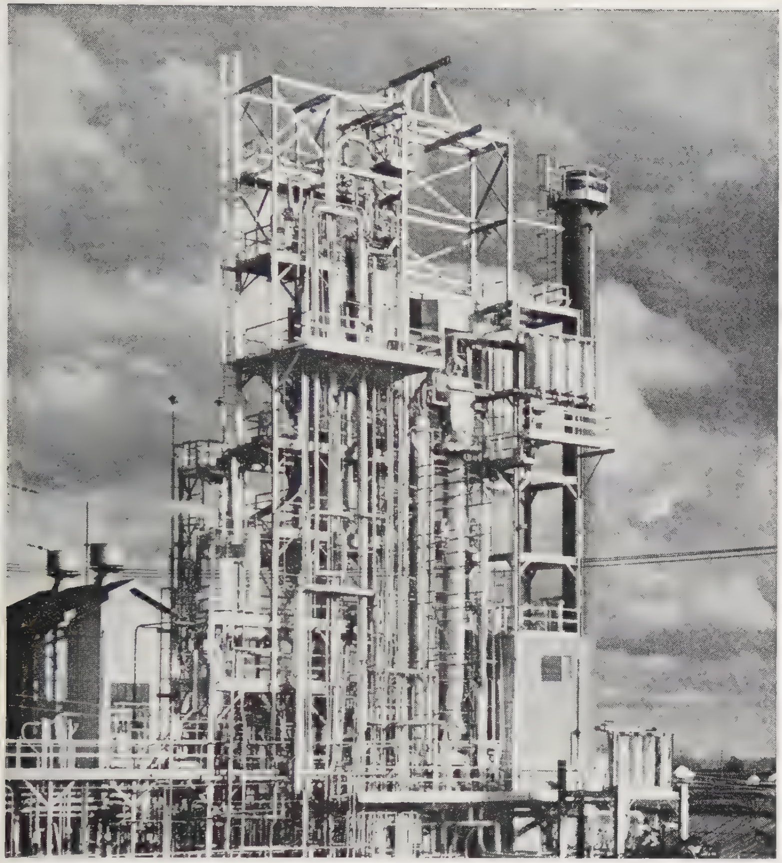
New petroleum fields have been discovered in the Prairie Provinces of central Canada.

One of the greatest potential sources of petroleum energy for the world is the Middle East. This oil must be developed to warm the homes, power the factories, fuel the agricultural machines, and move the goods of the people of Europe. In the past, most of Europe's oil needs have been met from the Western Hemisphere—especially the United States and Venezuela. But with the Western Hemisphere needing more and more of its own oil, it becomes increasingly necessary for the peoples of Europe and the rest of the Eastern Hemisphere to be supplied from the Middle East.

JUNGLE OIL

Some of the world's most important oil fields lie under the lush jungles of South America.

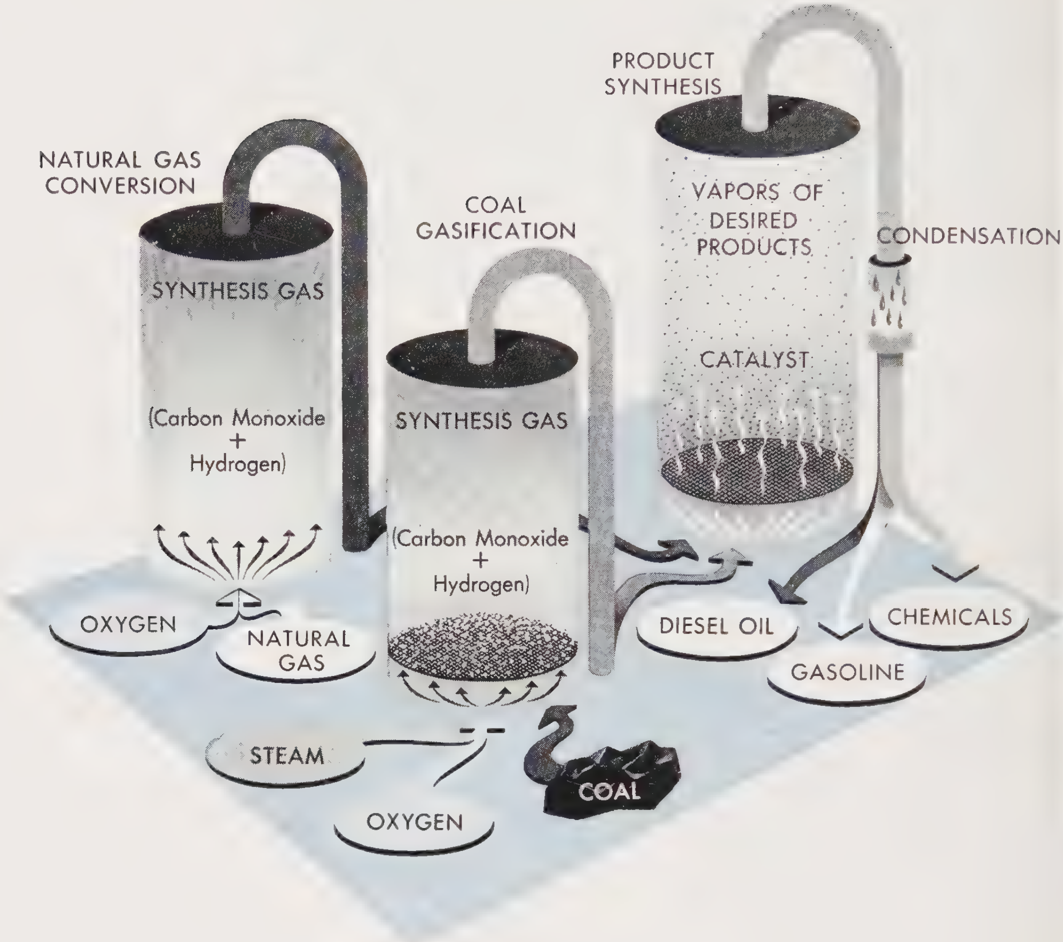
Fear over the possibility of running out of oil sometimes leads people to say that we should "conserve" our resources by restricting their use. Actually, conservation does not mean "nonuse." It means efficient use. It is by the *efficient* use of nature's gifts that we develop the culture, knowledge, and science which enable us to move on to progressively higher levels of living. It might be said, for example, that the Arabs "conserved" their oil for many centuries. But this oil, lying unknown in the ground, was of no use to the Arabs or anyone else.



NATURAL GAS SYNTHESIS

This pilot plant, several stories high, was used to test a new way of making synthetic gasoline from natural gas.

The advocates of nonuse also say that oil resources should be hoarded so that they will be available in time of emergency. But oil reserves take considerable time to develop. Even after a field is discovered, drilling and exploratory work must continue over a long period to establish its probable extent, the depth of the producing sands, and other information necessary to obtain the oil. Therefore, to hold up the development of a nation's oil fields until an emergency arose would mean that by the time those reserves were ready to use the emergency might have become catastrophe.



NATURAL GAS AND COAL CAN BE CONVERTED TO LIQUID FUELS

This process of changing natural gas or coal into liquid fuels takes place in two stages. The first stage produces a mixture of carbon monoxide and hydrogen. The second stage synthesizes from these gases the hydrocarbons which form the final products. Block A shows how synthesis gas is formed from natural gas; Block B how it is formed from coal. The final stage is shown in Block C.

There is, however, the inescapable fact that once oil is used it cannot be replaced. No one has discovered how to create new oil in nature's underground storehouses to replace that which has been drained. Eventually, we may need more oil than we can pump from the earth.

Fortunately, although crude petroleum is virtually the sole source of the world's liquid fuel at present, it is by no means the only possible source. The hydrocarbons which give oil its potential energy can be derived from coal, gas, oil shale, and even sawdust and cornstalks. Processes have been developed by oil companies and are being used on an experimental scale today to produce liquid fuels synthetically from coal, gas, and oil shale.

The coal reserves in the United States are extremely large. From this source alone, liquid fuel could be manufactured in sufficient quantity to supply the nation's needs for centuries and still leave enough coal for everyday use.

The known natural gas reserves in the United States are estimated at about 211 trillion cubic feet. The energy in this amount of gas is about one-third greater than that in our present proved reserves of crude oil. Although most natural gas will continue to be used as a fuel in the gaseous form, it is available for conversion to liquid fuel if needed.

Oil shale is a kind of slatelike rock which does not actually contain oil but holds in its pores a substance known as *kerogen*. When heated, the kerogen turns into a thick, heavy, evil-smelling liquid from which oil products can be refined. It is estimated that more than 75 billion barrels of oil could be obtained from the oil shale that is conveniently located in this country and rich enough to be worth processing. That would be more than double this nation's proved reserves of petroleum.

In the long run, synthetic processes assure us of an almost unlimited supply of liquid fuels. While it is technically pos-

EXPERIMENTAL OIL SHALE PLANT

The plant in the foreground is used to study new ways of obtaining oil products from oil shale.

sible to produce oil from almost any hydrocarbon source, the real problems are economic. The capital necessary for such energy conversion would be tremendous. To produce only our present requirements of gasoline from coal would, according to one estimate, call for an expenditure of at least 26 billions of dollars and would require 13 million tons of steel. Therefore, the development of synthetic fuels from coal will, under normal conditions, take place gradually and as justified by requirements.

In addition to energy from petroleum, natural gas, coal, and water-power, the energy of the atom has been unlocked and will ultimately be available. Atomic power probably

will not replace liquid fuels in automobiles or aircraft for a long time, if ever, but it seems likely that it may be applied to fixed power plants and perhaps to ships. In addition, there are perhaps untapped possibilities in the heat pump and the direct use of solar energy. And, so long as men's minds are free, there is always the possibility of a fundamental discovery of entirely new energy sources.

Although the world's supply of potential energy appears to have no limits, it is only "potential" until human effort and skill make it available in a form that can serve human need. In the final analysis, imagination, knowledge, and technical ability are among mankind's most important energy resources. With them it will always be possible to supply our fuel needs, whether from petroleum, coal, or other materials.

9

One of the oil industry's great achievements has been the development of techniques for handling petroleum and its products in great volume, with high efficiency, and at low cost. For example, to ship a gallon of crude oil from Louisiana to New York by sea costs as little as to ship a gallon of milk from one end of New York City to the other.

The principal instruments of oil transportation have been developed by oilmen to meet the particular needs of the industry. Drake's contemporaries built large wooden storage tanks near their wells, and pumped oil from them into wooden barrels for transportation to refineries. The barrels were loaded on wagons pulled by teams of horses, or on barges and river boats. At one time 6,000 two-horse teams and wagons were used in the Oil City, Pennsylvania, district alone, creating a traffic jam worse than those encountered in city traffic today.

As more oil was discovered, it became physically impossible to haul it in barrels, and oilmen turned to pipelines. Pipelines were not new; they had been used to transport il-

luminating gas for many years, and water pipes are older than written history. But early water mains usually sloped from the source to the delivery point, so that the water would flow along without pumping. And gas came out of the ground or from the manufacturing plants with enough pressure to push it along.

Oil was different. Nine times out of ten it had to be pumped with considerable pressure. The first successful "long-distance" oil pipeline was 2 inches in diameter and 5 miles long. It was built in western Pennsylvania in 1865 and delivered 800 barrels a day. After that more oil pipelines were built, even though the teamsters protested and occasionally fought pitched battles with pipeliners in attempts to wreck the lines.

The first really long-distance pipeline was built in Pennsylvania, from Corryville to Williamsport, in 1879. It was later extended to Bayonne, New Jersey. This line was 6 inches in diameter and could transport 10,000 barrels of oil a day.

The oil transportation system which has developed since those early days is a complex network of pipelines, tank ships, barges, railroad tank cars, and motor trucks. It carries crude oil to refineries and then moves finished products out to service stations and homes, to ship bunkers and airports, and to other supply points. But its key element in this country is still the pipeline.

The greatest pipeline mileage by far is in the United States. However, some major lines have been built elsewhere and others are planned. For example, there are five large lines from the Kirkuk fields in Iraq to the Mediterranean, a distance of about 600 miles, and a large-diameter line about 1,100 miles long has been built to carry crude from Saudi Arabia to the Mediterranean. The latter line provides a much shorter road for oil to Europe than the tanker sea-lane

through the Suez Canal. Also, an important crude pipeline, 1,750 miles long, has been built from the oil fields of Alberta, Canada, to the refinery area in Sarnia, Ontario.

In the field, crude oil is carried through *flow lines* into field storage tanks. *Gathering lines* from these tanks join a main line which carries the oil to a waterside terminal or to a refinery. Pipelines range from 2 inches in diameter for gathering lines up to 30-inch-diameter trunk lines. "Big-inch" is the pipeliners' term for any pipe over 12 inches in diameter.

The United States contains about 179,000 miles of crude

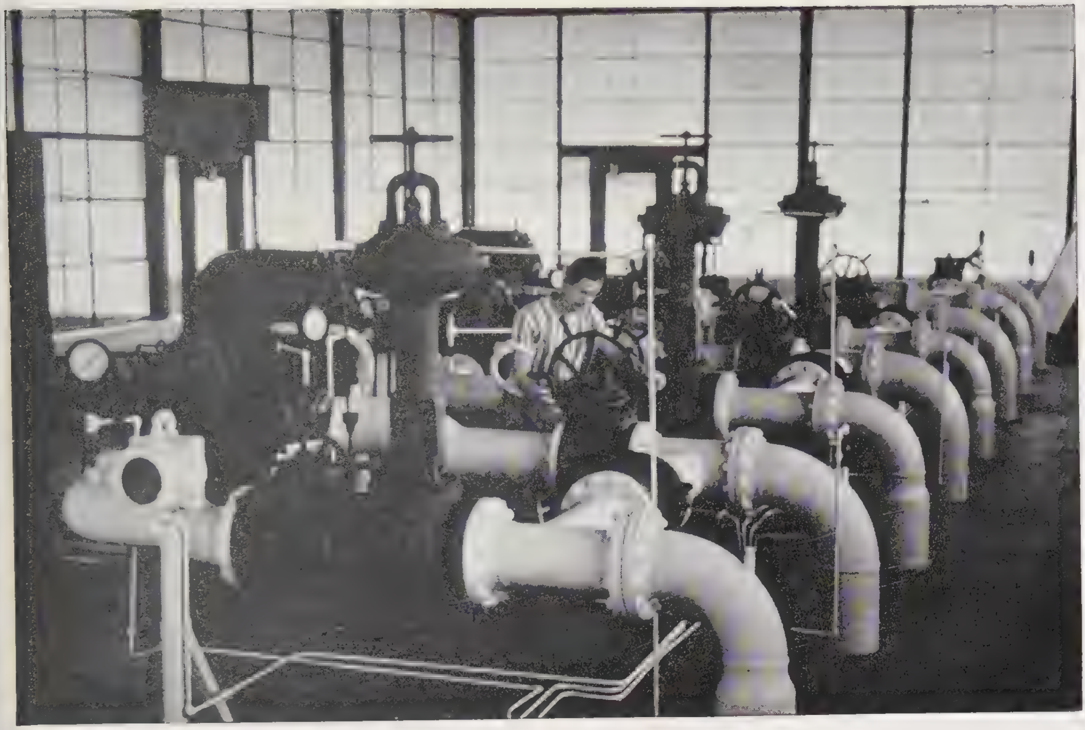
A veritable net of crude and product pipelines covers a major part of the United States.

INTERSTATE OIL PIPELINES

PIPELINES

CROSS COUNTRY

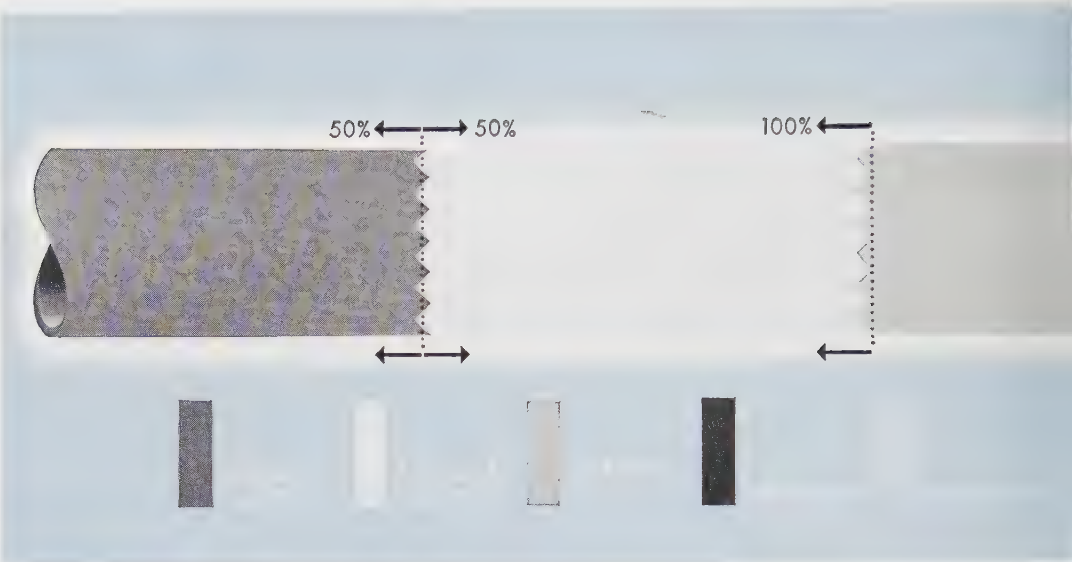
Crude petroleum and its products may move many miles by pipeline to reach their destination. In the picture above a section of pipeline leading to a tanker-loading terminal is being laid. At the right, long strings of pipe are put in trenches by side-boom tractors.



PUMP HOUSE

DISPATCHING OFFICE

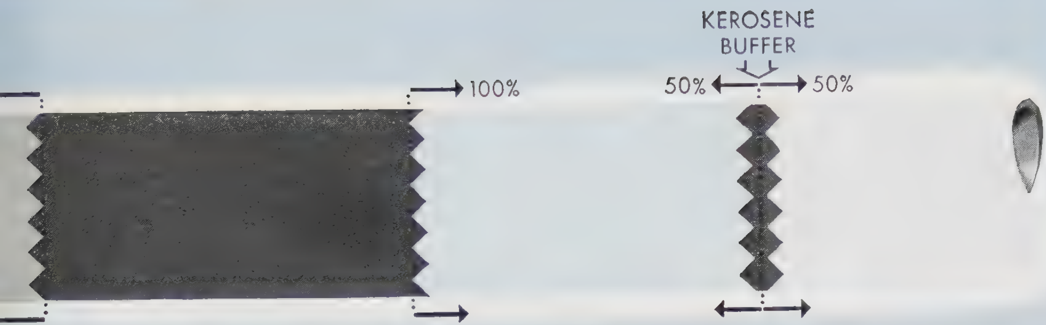
Pumping stations at intervals along the pipeline's route boost the oil over the hills and push it through the pipes. In pipeline dispatching offices, like the one at the left, the flow of oil in the line is carefully charted on long strips of paper, and the location of each batch in the line is always known.



SEQUENCE OF PRODUCTS THROUGH A PIPELINE

oil pipelines and about 30,655 miles of lines which carry finished products. With few exceptions, interstate pipelines are operated as common carriers, handling oil offered to them by any shipper. Anyone who drills wells in new territory in the hope of striking oil knows that if he finds it, a pipeline probably will be extended to his field and will continue to serve it from its initial stage of flush production right through the diminishing output of its final or "stripper" stage. The production of a single stripper well is small, but thousands of such wells over the country as a whole produce a considerable aggregate of oil. Much of this stripper production would be lost if it were not for the fact that pipelines normally continue to serve a field throughout its life.

The United States has more than 500,000 producing oil wells in twenty-nine states, and nearly 350 refineries in thirty-seven states. Of the total receipts of domestic crude at these refineries about 77 per cent, or something over 4,000,-



Many different oil products can be pumped through the same pipeline at the same time. Mixing is very slight if they are handled properly. As each product is removed from the line, the mixed parts may be allocated as shown. Sometimes kerosene "buffers" are placed between certain products to prevent mixing.

000 barrels a day, is delivered by pipeline. The remaining 23 per cent goes chiefly to waterside refineries by tankers and barges.

In point of tonnage handled, pipelines are the third largest freight carrier in the country. Their cargoes of bulk oil and products make up one-ninth of all the freight tonnage moved in the United States.

The first step in building a pipeline is to plan its route. This is done by study of maps and by aerial and ground surveys. Once the line's path is decided upon, hundreds or maybe thousands of property owners must be contacted to obtain a right of way. Then surveyors, bulldozer crews, and other construction men move on the job—marking, clearing, and grading the route. Powerful ditching machines dig the trench in which the line will be laid. Tractors with derricks lift sections of pipe 20 to 40 feet long. The sections are welded together on the site, and before the pipe is low-

ered into the ditch it is coated with special enamels and wrapped with heavy paper to protect it from corrosion. Most pipelines are buried. In sparsely settled regions, however, pipelines may be laid on top of the ground.

The route of a pipeline is plainly indicated in forest country by the cleared right of way. But in open country cattle may graze above the pipe and the wheat fields run unbroken, while the great man-made rivers of oil flow so silently and invisibly beneath the surface that few people are aware of their existence.

Power to move the oil through the lines is supplied by pumps. At intervals along the way, the pipe emerges from the ground and enters a station where the oil is given a thrust by powerful pumps before it dips again into the earth. In level country the pumping stations may be as much as 200 miles apart. However, intervals of 35 to 75 miles are more usual. Where the oil has to be pushed over hills or mountains, the stations are closer together.

Pumping stations are kept in communication with one another and with a central dispatcher's office by telegraph and telephone or radio. Into his office come reports from all the pumping stations and tank farms along the way.

Separate shipments of either crude oil or products are put into a pipeline one after another with no barrier between them. The head of the new stream butts against the tail of the one ahead of it with very little intermixing, and both form a continuous flow filling the entire diameter of the pipe.

How, then, is it possible to know when a particular shipment has reached its delivery point? Knowing the speed at which the pumps are moving it and the distance from the starting point to the delivery point, it is easy enough to calculate that it will arrive in, say, 132 hours. But this is not all.

Different crude oils differ in weight. The weight of oil is measured on a scale which the American Petroleum In-

"GO-DEVIL"

stitute has developed, and is expressed in terms of *A.P.I. gravity*. Suppose a particular batch of crude being sent through a pipeline has a gravity of 38° A.P.I. One-half hour before the head of the stream is expected to arrive at its delivery point, the operator begins drawing samples from the line and testing the gravity of each.

Go-devils are pipeline cleaners. The oil flow pushes them through the pipe, whirling and scraping as they go.

As soon as a sample shows 38° A.P.I., he turns valves which send the crude pouring into the tanks for the particular consignee. If the consignment amounts to 250,000 barrels, which is not exceptionally large, it represents a stream 330 miles long in a 16-inch pipeline and will require four days and nights of continuous pumping to deliver.

Pipelines are regularly cleaned by a bristling metal contraption known as a "go-devil." This device scrapes out the coating of sludge which collects inside the pipe. Because of the friction set up by its whirling arms scraping the inside of the pipe, the go-devil lags a little in the stream of oil which

carries it along and its scrapings are swept on ahead of it. You can hear them rattling through the pumps at any pumping station a half-hour before the go-devil itself clatters to a stop at its trap. Being unable to pass through the curving cross-over which leads the oil stream to the pumps, the go-devil travels only from one pumping station to the next. As soon as it arrives, a second go-devil, waiting bright and clean in its trap in the outgoing line, is let go; and the first is then hauled out of its trap and cleaned of the black and slimy mass which covers it.

Go-devils were named by the first pipeline walkers, the men who patrol the lines. They used to hear farmers say, as the clattering contraptions rattled along under the ground, "There goes the devil himself, bustin' out under my land."

The reassuring of farmers, however, is a very minor part of the pipeline walker's job. Just like a policeman, he has a regular beat to patrol, and he travels back and forth above the section of pipe assigned to him, looking for leaks or other accidents. He can spot leaks by smelling escaping oil, or by observing spots where it has seeped up to the earth's surface. Sometimes, especially in flood seasons, a sudden rush of water may wash the covering earth away from the line. In any of these cases, he gets in touch with his office as soon as possible, and in a short time a repair crew is on its way. In recent years many pipeline walkers have taken to the air, patrolling the lines with planes. Seepages and exposed lines are easily visible from a low-flying plane.

Crude oil lines have been developing for many years. On the other hand, the large-scale use of products lines to transport gasoline, kerosene, and fuel oil from the refineries to the marketing areas dates from as recently as 1930. Though still of relatively small mileage, products lines are the most modern of pipelines, demanding the most highly developed techniques. For example, the sampling of products is fre-

LAUNCHING

This is one of many new tankers that are being built to carry large oil cargoes at a speed of 16 knots.

quently done automatically, and valves are operated electrically by remote control.

Outside the United States more oil moves by tanker than by any other means. Much of the world's crude moves from oil field to refinery by ship, and a substantial amount of finished products also goes from refinery to market by tanker.

Although animal and vegetable oils had been barreled and moved by ship for many years, the first ocean-going ship designed to carry oil in bulk, and provided with pumps to handle its 700 tons of oil cargo, was the iron sailing vessel, *Atlantic*. The *Atlantic* was launched at Newcastle, England, on August 1, 1863. In 1886 the SS *Gluckauf* was built as the first ship ever designed from the keel up as an oil tanker. Its oil tanks extended to and included the metal skin of the

AT SEA

ship itself. This feature is still used, though there have been many changes in the hull design and machinery of tankers.

The modern tanker is unlike any other ship that sails the seas. Its hold is divided into a number of compartments so that it can carry crude and products—or different types of each—during the same voyage. Its decks are patterned with pipes and valves by means of which cargo is loaded and discharged. The distinctive external appearance of tankers makes them easy to recognize at sea or at anchor. About one-third of the way back from the front of the ship, or "aft of the bow," as a sailor would say, is a large structure which contains the bridge, living quarters for the officers, and the radio and chart rooms. At the stern is another structure with living quarters for the crew. Engine spaces are directly under

ON DECK

Ocean-going tankers are trim, fast ships, built to carry oil products to people all over the world.

SIGNING ON

Jobs aboard tankers are considered among the best in the merchant marine.

this part of the ship, and the funnel, or smokestack, projects above it.

More than 2,000 ocean-going tankers, each capable of carrying 6,000 or more tons of oil, make up the world's commercial tanker fleet. About a fifth of this fleet is owned in the United States.

In general the larger and faster a tanker, the lower the cost of transportation. The average American tanker can carry about 15,000 tons and has a speed of 14 knots, compared with the prewar ship of about 11,500 tons and speed of 10 knots. Today tankers of 26,000 tons and more are being built. These 26,000-ton vessels steam at 16 knots. Each of them can carry enough petroleum to fill 950 railroad tank cars, which would make a train about 7 miles long.

END OF TRIP

A quick turnabout is also important to successful tanker operation. With proper shore facilities a modern tanker can load or discharge an entire cargo in less than a day. When we consider that it costs several thousand dollars a day to keep a big modern tanker at dockside, the importance of holding port time to a minimum can be appreciated.

When the voyage ends, the crewmen may leave the ship or stay for the next trip to sea.

An elaborate system of records and radio reports enables the headquarters of tanker fleets to know the exact location of each vessel wherever it may be on the seven seas. This makes it possible to keep petroleum supplies moving with precision and dispatch from where they are available to where they are needed.

A job aboard a tanker in peacetime is considered one of the plums of the merchant marine. Good quarters, excellent

food, high pay, and a trim, seaworthy vessel are attractions which cannot be matched by any other service afloat. In some of the larger fleets, liberal provisions for vacations ashore are an additional attraction. The normal complement of an average American tanker consists of nine officers and thirty-three men.

More than half of all supplies shipped overseas from this country during World War II were petroleum products. This meant that tankers had a vitally important role to play in all the Allied military and naval operations.

It was the tanker fleet that made it possible for the United States to fight a major war on two fronts simultaneously and at immense distances. Some of our Pacific supply lines lengthened to 14,000 miles, more than halfway around the globe, as offensives were mounted in areas where no regular bases existed.

Fleet Admiral Nimitz called the technique for refueling at sea his "secret weapon," for never before in history had a huge fighting naval force been independent of its shore bases for more than a few weeks at a time. Refueling at sea was work calling for the utmost skill in seamanship. Two ships, each weighing thousands of tons, had to be jockeyed into position only a few feet apart, and kept that way while they plowed ahead through heavy seas. Refueling might go on at night and in almost any kind of weather. A single tanker sometimes fueled as many as a dozen ships within twenty-four hours.

Greater ease of handling, less bunker space, fewer firemen, and no smoke to betray a ship at sea—these are some of the advantages of oil for combat vessels. But its greatest advantage is the increased radius of action which it makes possible.

In 1942 and on into 1943 the Nazi U-boat packs attacked with stunning ferocity, lying in wait along the tanker routes, especially in the Caribbean and off the east coast of Florida.

More than fifty-seven tankers were sunk in Atlantic waters in the first five months of the war. The U-boat war was costly on three counts—the toll of human lives was high, vitally needed shipping was lost, and precious oil was destroyed.

In the latter part of 1943 tanker construction began to hit its real stride, and by the end of 1944 we were replacing tankers far faster than they were being lost. The men who sailed the tankers and the men who built them contributed mightily to the final victory.

During World War II the difficult art of refueling ships from tankers while under way was perfected.

REFUELING AT SEA

We have described the transportation of oil by land and by sea. Rivers, canals, and lakes also are important channels of oil commerce. More than one million barrels of petroleum and its products are transported *daily* in the United States on inland waterways.

BARGE CANAL

Long strings of oil barges, pushed by powerful tow-boats, travel along the waterways of the nation.

Following the discovery of oil in Pennsylvania in 1859, inland waterway transportation began with the use of rafts steered by poles and floated with the current from the upper reaches of the Allegheny River to the Pittsburgh area. Since that time the industry has developed a highly specialized

type of steel tank barge, equipped with its own pumps. These barges have an average capacity equal to between forty and fifty railroad tank cars. They usually move in flotillas of up to ten or fifteen barges pushed by powerful "towboats." One or more barges are released as discharge

MISSISSIPPI RIVER

terminals are reached on the route. The towboat with the remaining barges continues on the voyage, thereby avoiding the laying-up of the power plant while barges are being discharged, as would be the case with a self-propelled barge. Barges are extremely important for inland transportation of

The skyscraper capitol of Louisiana, at Baton Rouge, sees many loads of oil go by on the Mississippi.

oil, particularly in such areas as the Mississippi River system.

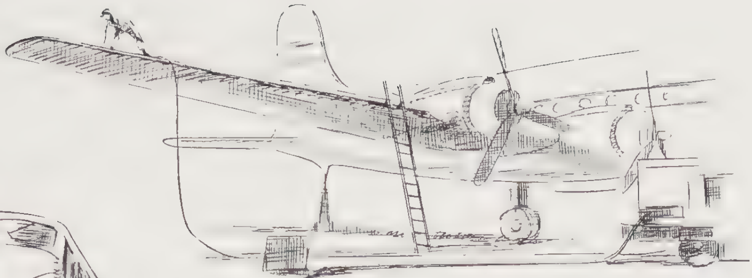
While barges are plodding up the rivers at their steady 5 to 8 miles per hour, railroad tank cars are moving oil products at freight-train speeds to distributing centers big and little and to some of the larger individual consumers. Few tank cars are owned by the oil companies themselves. Nearly all are owned by companies which make a business of building and operating such cars. About 115,000 of these cars are in service.

Twenty years ago much of the movement of products from refinery to distributing centers was by tank cars. Today they are used mainly for hauls above 200 miles. Shorter hauls are made mostly by tank trucks on the highways. It is the tank truck which usually carries oil on the last leg of its journey to the consumer. There are about 200,000 of these trucks in the United States, and they serve hundreds of thousands of retail outlets, at the country crossroads as well as in the big cities.

Tankers, pipelines, river, rail, and road vehicles, down to and including the pushcarts of kerosene peddlers, form a transportation system which reaches consumers all over the world. The system might be described as the arteries of our industrial civilization. By efficiently linking the producing fields on one end with the refineries and markets on the other, it is one of the chief factors making possible the petroleum industry's very low cost of distribution—a saving which is passed along to the consumer.

TANK CARS

Railroad tank cars have long been important in the overland transportation of oil. Today's tank cars are a far cry from their earliest predecessors, which were little more than wooden barrels mounted on flat cars. The cars shown in the picture above are being loaded with oil products at a refinery. When filled they will probably be hauled to bulk stations, where their contents will be distributed by tank trucks.



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Over nine decades have elapsed since the birth of the oil industry. Those ninety-five years have seen the development of more and more efficient methods of getting the oil out of the ground, of preparing its products for the consumer's use, and getting these products to him. In the early days the products chiefly sought were kerosene for lamps, fuel and "road" oil, harness oil and axle grease, and a few other lubricants. Gasoline, an unavoidable by-product of the distillation process, was regarded as a nuisance and was generally thrown away. Then the invention and mass production of the automobile created a great demand for gasoline. In fact, it became the most important petroleum product.

Today the oil business is a balanced industry; no longer are there any "by-products." Just as it has been said that the packing industry uses all the parts of a pig except its squeal, it has been said that the oil industry uses everything in crude oil except its smell. Actually even that is used today. It is added to otherwise odorless gases to help in the detection of leaks in pipe systems.

CLOVER LEAF

Over America's highway system, goods roll to market and people travel comfortably about the country. The petroleum industry has played an important part in the growth of motorized transport.

As we have already mentioned, methods have been discovered during recent years for obtaining from petroleum a large variety of new products, and of making products from oil which previously were made from other raw materials. But the principal use of petroleum today is still as liquid fuel. The oil industry is really a business of producing and delivering energy; it is in competition with the other chief energy industries—coal, natural gas, and hydroelectric power—and as the years go on it may also have to compete with atomic energy.

Thousands of companies and millions of people make up the oil industry. Just before the outbreak of World War II, the Temporary National Economic Committee of the United States Senate issued a study of the country's oil industry in which twenty oil companies were classified as "majors." This is more than can be found in any other basic industry. Besides these major competitors, there are thousands of smaller companies actively engaged in one or more divisions of the business.

One of the largest American oil companies is Standard Oil Company (New Jersey). Yet its affiliates have less than 15 per cent of all petroleum products business in this country. They produce less than 10 per cent of the crude produced here, and have under lease only about 2 per cent of the country's potential oil acreage. Companies in the oil business range through all sizes, grading from the little ones into the big. All of them contribute importantly to the overall picture of our oil economy. The large organizations can do some things more efficiently than the small ones, and the small operator can do things which are impractical for the large operator.

Because it brings together the capital of great numbers of people and so has greater resources, the large company can undertake mass production and mass distribution in markets

which warrant it. This results in marked economies for the consuming public. The large company can embark on costly developments which may take years to consummate and which would exhaust the resources of a smaller company before the work began to show a return.

On the other hand, the small operator, using his own capital, responsible to no one but himself, can sometimes take risks which the directors of a large corporation, as employees of and responsible to a large number of stockholders, may not feel justified in taking.

Among the various divisions of the oil industry—producing, refining, transportation, marketing—the one in which the large companies have the greatest share is refining. Refining is primarily a mass-production, intricate manufacturing operation requiring huge investment in equipment. The companies designated as "majors" have about two-thirds of the country's refining capacity. No one of these companies, however, has more than 12 per cent of the total capacity, and, even in refining, the majors are by no means the only factor. Some 150 companies own about 33 per cent of the nation's capacity.

In the producing phase of the business, the so-called "minor" units account for approximately half of the nation's output of crude oil. They own between 65 and 75 per cent of all the wells.

The retailing aspect of the oil business is done by thousands of small businessmen. There are about 15,000 jobbers and some 200,000 retailers in the United States. The great majority of them are small, independent businessmen who run their own affairs and who, if they want, can stop handling one company's products and handle someone else's.

Most of the large corporations engaged in the petroleum business are so-called "integrated" companies. This means that they perform several or all of the separate operations

which take place beginning with exploration for oil and ending with delivery to the customer. The reasons for integration are particularly compelling in the oil industry because of its characteristic of continuous-flow operations, the interruption of which would have very considerable impact on costs and prices.

American capital is widely invested in oil operations in other countries, and American technology has been extensively used to develop oil resources in all parts of the globe. One factor concerning the foreign business of American oil companies which is not always recognized is that this sort of foreign trade does not primarily involve export of oil from the United States. On the contrary, much of this trade consists of producing oil in one foreign country, perhaps refining it in another, and selling it in still others. Such oil never touches United States soil. The real United States export in these cases is investment and skill.

The contributions to higher living standards abroad by American companies operating in foreign countries were singled out for comment a few years ago by a United States Senate Committee that had made an exhaustive study of the oil industry. The Committee's final report to the Senate contained the following passage:

> The prospect of improved living standards abroad is further enhanced by the manifold benefits to foreign countries through the very presence of the American oil investment therein. Likewise the social and educational benefits, resulting from the American investment and the policies of the companies, are manifold. Thus, in 1937, royalties and taxes paid in all foreign countries by American petroleum companies exceeded $687,000,000. Thousands of the nationals of these countries find welcome employment, skilled and unskilled, by the oil companies, and other thousands find employment indirectly as the result of such large-scale operations. Homes, hospitals, schools, highways, port works, power and light plants, telephone and telegraph lines, airports, water wells, facilities for drainage irri-

gation, sanitation, etc., have been constructed in many parts of the world where they had been rarities. It is of small moment that some of these improvements were motivated by a policy designed in the long run to profit the companies. The local benefits are no less real because business enterprise is sufficiently enlightened to cultivate goodwill.

Investment in the petroleum industry in the United States is greater than that in any other single field with the exception of agriculture and the combined utilities group, which includes gas, electricity, and communications.

More than 200 different taxes, including state and federal gasoline taxes, registration and inspection fees, and many others, are collected from the industry. There are taxes on almost all oil products, and the yearly income to government from this source alone—and not counting other taxes paid by the industry—amounts to more than three billion dollars. In addition, the industry pays corporate income taxes amounting to about one billion dollars a year.

The importance of American enterprise to the world's oil supply is indicated by the fact that the United States has produced more than 60 per cent of the petroleum so far produced in the world. This has been done despite the fact that our country contains only 10 per cent of the earth's rock formations favorable for the presence of oil. In other words, with only one-tenth of the world's potential for finding oil (and with only one-fifteenth of the world's population) we have found and developed within our own borders more than one-half of the oil produced up to this time.

The success of American oil enterprise is probably a result of our form of government and society—of democracy. In our country individuals are not restricted by birth nor by government edict to any particular economic level. Everyone has a chance to improve himself. One of his ambitions may be to make money so that he can increase his portion of

EDUCATIONAL BENEFITS

Overseas, in some countries where oil fields have been developed, the oil industry provides schools and other facilities for the employees' children.

the world's goods. One way to make money is to find oil. So in the United States we have had a great many people looking for oil—more than any other country has had.

No restrictions have been put on the search. A farmer, a barber, a professor of geology who could scrape together

FOREIGN HOUSING

This Venezuelan worker's home, where he lives with his family, is typical of the houses that American oil companies provide for the nationals they hire.

enough money to drill a hole could, if he wanted, risk his money on the chance of "striking it rich." As a result, we have found the oil that has helped build America's industrial capacity and made possible its motor transport.

In contrast with this method of developing oil resources, consider what has happened in the rest of the world with its 90 per cent of the globe's potential oil lands. Some nations have reserved to their governments the sole right to develop

oil resources. And they have been conspicuously unsuccessful. Some countries allow only their own citizens to look for and develop oil. In other countries the government holds stock control of the dominant oil company and favors it in competition with private companies.

GAS STATION

In America we believe that such restrictions or centralized control hamper full, reasonable development and utilization of oil resources. It has been the absence of arbitrary and artificial restraints in this country which has led to our pre-eminence in oil.

Modern service stations are usually operated by independent businessmen who own or lease them. They provide a complete service for motorists.

Over a million and a half people are engaged in the oil industry in the United States alone. Some 300,000 men work in the oil fields, prospecting and drilling for oil; an-

other 129,000 are engaged in moving oil and its products over land and sea. There are more than 236,000 refinery workers. These people produce, transport, and manufacture the oil products used by 162 million Americans, who buy

ELECTRICIAN

EXPLORER

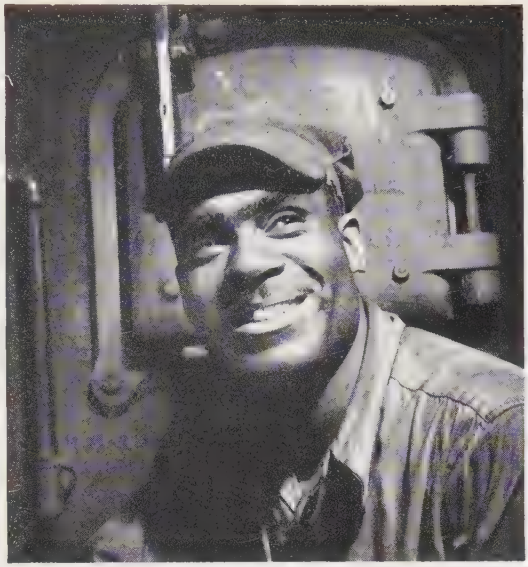
petroleum from 242,000 wholesale marketers and 761,000 service station attendants.

The number of jobs that petroleum provides has increased about 40 per cent since World War II, while the output of each worker has increased 50 per cent in that time. The rapid growth of the industry and technological advances now enable the same man to do more work than he formerly did, and as a result he is better paid than most other industrial workers.

Thousands and thousands of people have invested their money in oil and depend on it for all or part of their income.

The oil business is one of the biggest employers of capital in all industry. It is estimated that an average of $20,387 capital investment is required for every petroleum worker. By comparison, the coal industry requires an investment of

TOWBOAT CAPTAIN



OILER

about $5,100 per employee, the metal products industry $8,900, and the food processing industry, $11,400. The average for all industry is around $9,500.

A steadily growing oil industry provides interesting work and opportunity to thousands of men and women.

Ages ago nature laid away stores of petroleum energy which have helped us attain a level of living not even dreamed of by the richest of ancient kings—or even by our own grandparents. But nature left the recovery and application of this energy to man's own initiative, to his inventiveness, and to his daring. So long as he uses them, he can look forward to even better things.

ROAD REPAIR

For almost a hundred years petroleum has provided the world with fuels and lubricants and many other products that have contributed to man's progress. Petroleum asphalt, for example, has helped to build the highway systems of many countries and paves much of the earth on which great cities are built.